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TAMPERE UNIVERSITY OF TECHNOLOGY

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DEFINING SUPPLIER RELATIONSHIP MANAGEMENT SYSTEM REQUIREMENTS FOR AN EPC FIRM: A CASE STUDY

Master of Science Thesis

Examiner: Professor Samuli Pekkola
Assistant Professor Henri Pirkkalainen
Examiner and topic approved on

ABSTRACT

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Improved information technology has reduced the barriers to access international markets, businesses nowadays buy or sell from or to anywhere in the world. Globalization has also encouraged companies to do business far away from their domestic markets. Efficient logistics has enabled companies to manufacture their products in one country and sell it anywhere around the world. Additionally, outsourcing trends have made companies transfer non-core activities to other parts of the supply chains.

All these factors have made the supply networks complex and spread all over the world, at the same time businesses have become more dependent on their suppliers. In order to efficiently manage these supply networks, companies have focused on the developing relationships with their suppliers. Supplier relationship management (SRM) has been researched and abundant authors have written about this subject. Many software companies have developed SRM system to assist companies in managing supplier relationships.

Engineering Procurement Construction (EPC) firms work with a large number of goods and services suppliers for any investment projects. The nature of this industry significantly differs from that of manufacturing industry; however, most of academic literature on SRM is focused on manufacturing industry. Most of the systems for supplier relationship management are built with manufacturing industry being the primary focus as well. The objective of this thesis is to define the requirements for SRM system for an EPC firm delivering processing facility investment projects.

To define these requirements, 19 people from the case company, working in indifferent departments, were interviewed to gather the information regarding their needs. Elicited requirements were focused on supplier information management, requisitioning and operative purchasing, product catalogue management, and supplier performance management. Additionally, supplier relationship management activities that are of most interest to an EPC firm were identified as; supplier performance management, supplier selection process, and supplier evaluation.

PREFACE

I would like to express my sincere gratitude to Dr. Henri Pirkkalainen for the immense support and valuable guidance during this work. I would also like to thank Dr. Samuli Pekkola for the supervision fro thesis. Moreover, I would like to thank Mr. Eero Rauvola at the case company for getting me the opportunity to do my thesis for the company.

Tampere, December 2017

Husnain Sikander

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1. INTRODUCTION

1.1 Motivation

Globalization and modern information technology tools have reduced the barriers to accessing global markets, these days businesses are able to buy and sell virtually from or to anywhere in the world. This ease of access to international suppliers has led to businesses acquiring goods and services more than they have ever before, particularly in the developed economies (Liker & Choi, 2004). Supply chain practices have enabled businesses to manufacturer products in one place and sell these in any part of the world. For customers, this creates the need to gain more knowledge about the supply network (Trent, 2005). Services, particularly knowledge intensive services, such as; expert consultancies, software services, designing among others, can be sourced from external suppliers located anywhere in the world.

Companies are becoming increasingly dependent on the suppliers to reduce costs, better quality products, and the development of new products or services (Liker & Choi, 2004). In order to manage this complexity and diversity in the supplier base companies have focused on supplier relationship management (Park et al., 2010). Supplier Relationship Management is the process of developing and maintaining the relationship with suppliers in a structured manner (Lambert & Schwieterman, 2012). There is abundant literature available that discusses various activities in the supplier relationship management process such as; supplier selection, supplier development, risk management, and performance management (Liker and Choi, 2004; Svensson, 2004; Neely, Gregory and Platts, 2005; Leenders *et al.*, 2006; Mentzer Jr, Myers and Stank, 2007; Fogg, 2009; Park *et al.*, 2010; Sundtoft Hald and Ellegaard, 2011). To support these activities, a large number of software solutions are commercially available by various software companies as well.

However, most of the discussion in the academic literature is focused on the manufacturing industry. There is lack of information available from the perspective of a professional services provider; how the emphasis on different activities of the supplier relationship management process could be affected for the businesses who do not, as such, manufacture a product, such as Engineering-Procurement and Construction (EPC) contractor. Similarly, most of the software solutions are geared towards the needs of manufacturing businesses. Therefore, the aim of this thesis is to identify requirements for the supplier relationship management system for an EPC firm.

1.2 Research Objective and the Case Company

The target organization of this study is a Finnish engineering company focusing on process industry investment projects. The company delivers engineering procurement and

construction management (EPCM) projects for clients in Oil & Gas, petrochemical, chemicals, and biodiesel refineries. Company has three offices in Finland, and overseas offices in Sweden, Netherlands, Singapore, UAE, India, and Azerbaijan. Case company carries out investment projects of various sizes, from small upgrades to turnaround projects for the large-scale process facilities. Moreover, in future, company intends to deliver EPC or turnkey projects as well. Currently, company does not have a supplier relationship management system and primarily uses the suppliers recommended and approved by the clients.

As company moves towards more EPC projects, there is a realization in the management that it would need to develop and maintain its own base of goods and services suppliers. Moreover, company's long-term strategy includes the digitalization of its processes as much as possible. In the current stage of this multiple phase strategy, the company is acquiring a material management system to insure material visibility from identification of the need to the final consumption of a product. This whole process is closely related to interaction with suppliers, and in proceeding stages of the project company intends to acquire a supplier relationship management system as well. Therefore, the goal of this thesis is to…

…define supplier relationship management system requirements for an engineering procurement construction (EPC) contractor..

In order to approach the research goal from an EPC contractor's perspective, this thesis tries to probe the following sub questions:

- What are the current SRM practices?
- What activities of the SRM process are the most relevant to an EPC contractor?
- What are the processes related to supplier interaction where a digital system could bring improvement?

The first question will help understand the current state of SRM practices in the company through reviewing existing company processes. Second, what are the key activities of supplier relationship management that an EPC contractor should focus on the most? Lastly, third question will help identify the parts of the process where implementing a digital system could bring improvements. In this thesis, a qualitative approach is utilized by conducting semi structured interviews with internal employees of the case company. Based on this, the key themes are identified that are raised in the interviews. After identifying and analyzing the most common responses, the requirements for SRM system for EPC contractor are defined.

1.3 Research Methodology

This part describes the research method adopted for this thesis.

1.3.1 Research Framework

The research framework for this thesis is based on the model presented by Saunders *et al.*'s (2009). It explains the chosen research philosophy, the research approach, research strategy, time-horizon, data collection methods. It is shown in Figure 1.

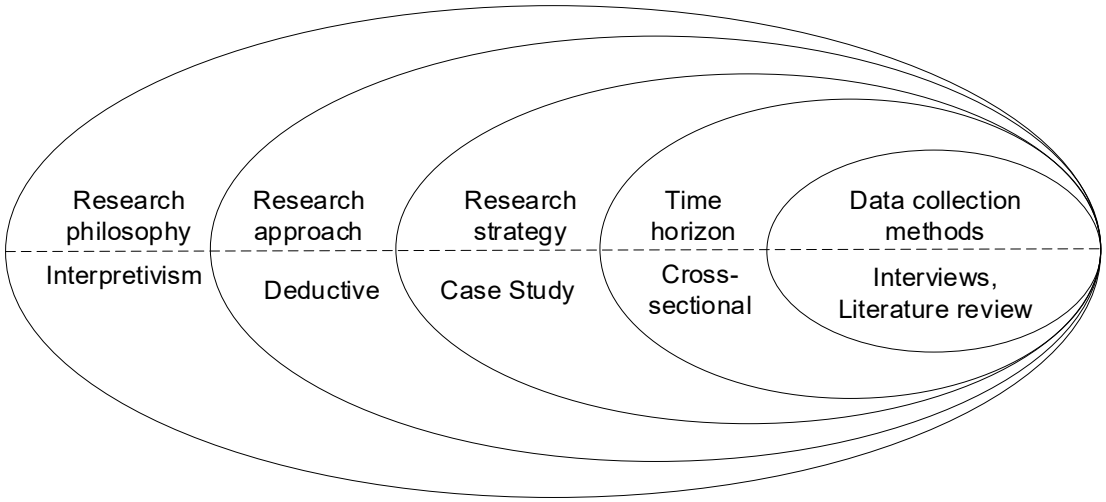

Figure 1 Research framework the thesis (adapted from Saunders et al. 2009).

There are four dominant philosophies on conducting empirical research, positivism, constructivism, and pragmatism (Creswell, 2003). The methods selected, for getting an acceptable evidence in response to a research question, are greatly affected by the adopted philosophical stance. Constructivism, also called interpretivism (Klein and Myers, 1999), states that the scientific knowledge cannot be separated from its human context. Constructivists are more concerned with understanding how different people make sense of the world and attach meaning to a phenomenon, than with verifying a theory. It is possible that theories may emerge in the process, but they always depend on the context under study. This stance advocates collecting rich data about human activities or processes in an environment (Easterbrook *et al.*, 2008). As, the purpose of this research is to define the system requirement, this necessitates understanding the human and process need in a particular social context and therefore interpretivism stance to research is adopted.

Deductive and inductive reasoning are the two recognized approaches to analysis; inductive analysis is aimed at making broader generalizations based on specific observations. Deductive reasoning, on the other hand, is a top-down approach that starts out with a general theory or statement and narrows down to more specific matter. Since, the aim is to specify the requirements based on the collected data and understand the human and process need, hence inductive reasoning is the chosen approach here.

Yin (2003)states that case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". Case studies are an effective tool to thoroughly understand a phenomenon and the reasons behind its occurrence. Easterbrook *et*

al., (2008) has explained two types of case studies in software engineering research: exploratory and confirmatory case studies. Exploratory case studies are used to investigate a phenomenon to build new theories whereas confirmatory case studies are used to prove or refute existing theories. This study is an exploratory case study, with the aim to understand needs of the users and define the requirements that a system should meet.

The time horizon in Saunders *et al.*'s (2009) framework refers to the duration of the research study, they have presented two type of time horizons; cross-sectional or longitudinal. Longitudinal horizons refer to longer period research and in cross-sectional time horizons studies, subjects are studied only for a restricted period. Since the research was conducted in a limited time, which by definition is the cross-sectional time horizon. The data collection techniques used for this research were qualitative interviews, literature review, and case company's documentation. Some Interviews are usually considered a part of other methodologies such as case studies; however, others regard interviews as a separate category (Damian and Chisan, 2006). Interviews are considered an effective tool for collecting valid, reliable and relevant data Saunders *et al.*'s (2009). Qualitative interviews are a conversation between the researcher and respondent, these interviews could be structured or unstructured. In structured interviews, there is a set agenda and the researcher asks questions from the respondent, on the other hand, in unstructured interviews there is no fixed agenda and there is a free style conversation. However, in practice even unstructured interviews have some agenda to keep the conversation form digressing (Eriksson and Kovalainen, 2008) therefore, most of the interviews for research purposes are semi-structured.

1.3.2 Research Process

This research was conducted as case study in order to explore the system needs for personnel in a certain context. The processes started with the task of defining the system requirements for an SRM system at the case company. Currently, company delivers process industry projects with EPCM contracts and intends to move towards delivering EPC contracts. In order to better understand the EPC projects, information related to EPC project lifecycle was collected. Next, the differences between these two contracting strategies were studied to understand how the role and responsibility of the company would be affected when moving from EPCM projects to EPC projects. Since the supply chain of construction industry differs from the manufacturing industry supply chain, these differentiating factors were reviewed from academic literature.

The concept of supplier relationship management is not a new one; however, there still some ambiguities around it. To clarify the definition of SRM and the reasons for adopting SRM was studied from the academic literature on this subject. There are various models described by different authors to classify the relationships with suppliers, some of these models were reviewed to get an understanding how and why these differences occur. Since, the company did not already have am SRM processes therefore information about

different SRM activities were collected with the purpose to identify which activities could be relevant to the case company.

Reviewing concepts related to software requirements was felt important to fully understand what are software requirements and their types. In order to define requirements that would be acceptable, the characteristics of requirements were studied. This information helped in developing requirements that were complete, accurate, and clear. In the final part of the literature review, the process of requirements development was studied and to get the understanding how the requirements should be elicited, analyzed, and documented. This concluded the theoretical part of the research processes. The complete research process is shown in Figure 2

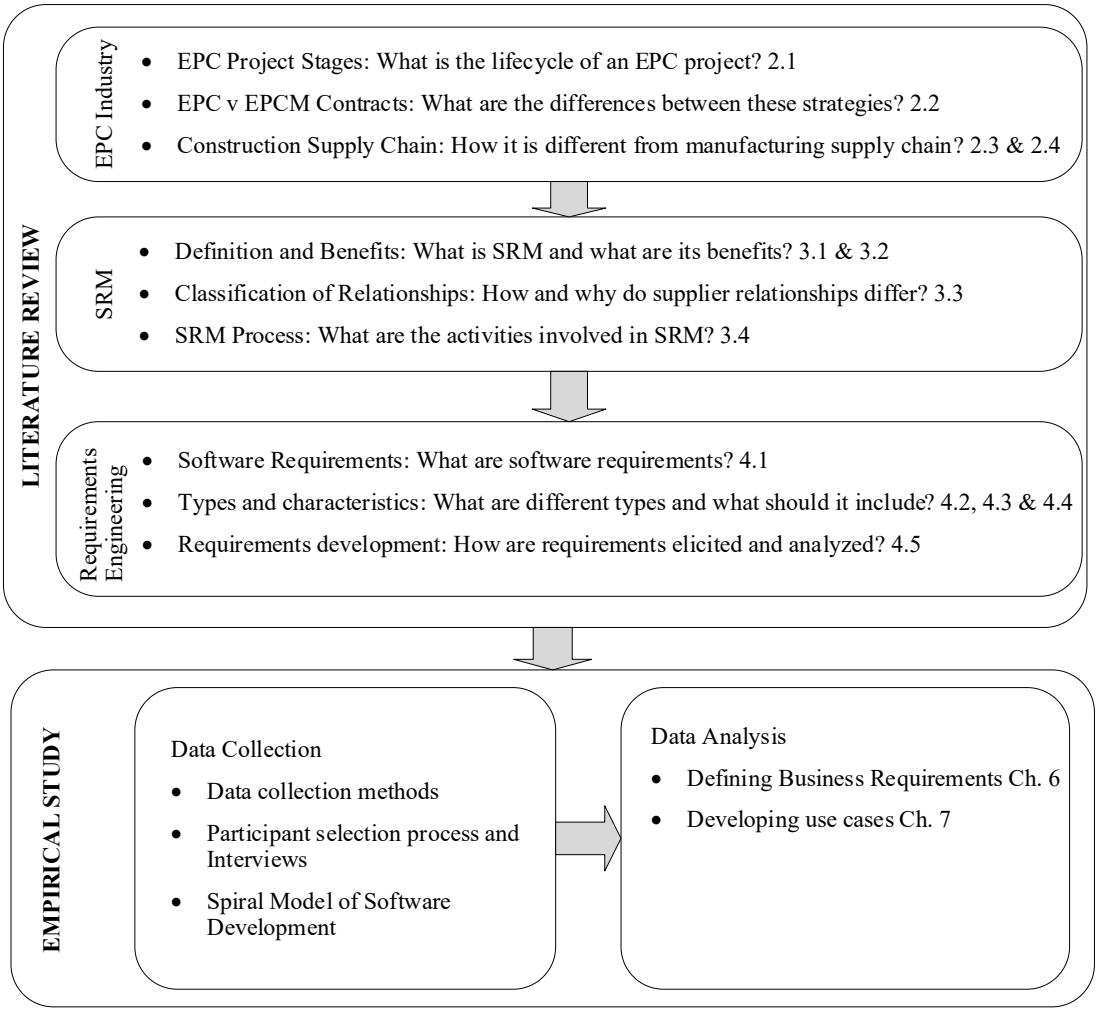

Figure 2 Research process.

Data Collection

During empirical study, semi structured qualitative interviews was used as the primary data collection method. Additionally, in order to understand the current situation current

company processes & practices were studied. The information related to key activities in the SRM process was collected from the academic literature and used to develop the interview framework, shown in Appendix A. Firstly, key activities related in SRM process in the context of an EPC contractor were identified through literature review, qualitative interviews, and through existing practices. Second, through interviews and company's literature, the current state of SRM was identified. Also through interviews, the need for the system was identified. Figure 3 shows the date gathering method for each purpose.

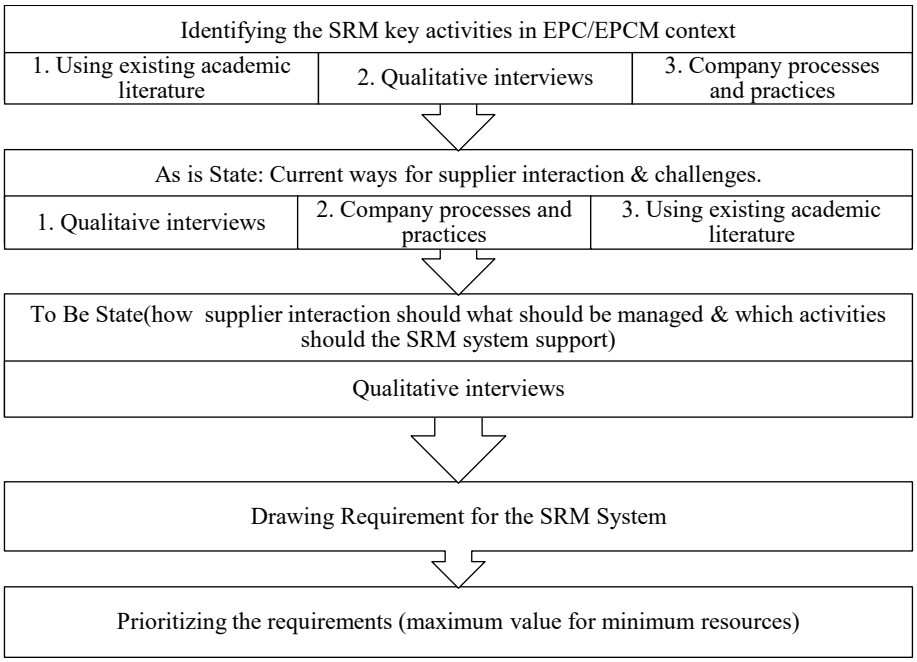

Figure 3 Data gathering methods

Participant Selection Process and Interviews

During an EPC project for building a process industry, various disciplines in the EPC contractor's organization need to interact with suppliers. For example, during the delivery a large pump or a compressor, procurement is involved in operative purchasing and expediting, different engineering disciplines interact with the suppliers for various design related matters, project management and construction management organization work with the supplier during the installation and commissioning phase. Therefore, all these functions are important stakeholder for implementing an SRM system. To collect the data from various stakeholders' perspective, people from all these functions were interviewed. To select the participants from each function, corresponding department head were requested to nominate the most suitable participants for research.

A total of 19 internal employees from different departments were interviewed. From Engineering, one Lead Design Engineer for each of the Electrical, Instrumentation & Con-

trol, and Mechanical Rotating Equipment were interviewed. From Procurement, five project procurement managers, two purchasers and two senior expeditors were interviewed. From Construction Management, one construction manager and one construction consultant were the participants. From Project Management & control department, two project control managers, one project planning manager, and one engineering manager were included in the research. Additionally, the manger for Business System Support was also interviewed to get information regarding the requirements definition practices at eh company. Table 1 below shows the breakdown of interview participants according to the department.

Table 1 Breakdown of interview participants.

Department	Interviews
Engineering	3
Procurement	9
Construction Management	2
Project Management & Control	3
Business Support	1

Fifteen people were interviewed individually and four people were interviewed together with two people in each interview session, interviews duration was 45 minutes to 60 minutes. Fourteen people were interviewed face to face and five interviews were conducted using an online meeting platform. Seventeen interviews were recorded with the permission of the participant while two participants did not consent to record the conversation.

Spiral Model of Software Development

Comprehensive system requirements for the case company can be defined when viewpoints of different functions and from different geographic location are taken into consideration. Therefore, a lean approach to requirements elicitation is employed. The Spiral Model of Software Development (Boehm, 1995) is followed as shown in Figure 4. Requirements are gathered, analyzed, documented and validated, in cyclical manner. One of the major strength of this model is the active user participation to determine the final requirements. This also helps eliminate the redundancy in the data.

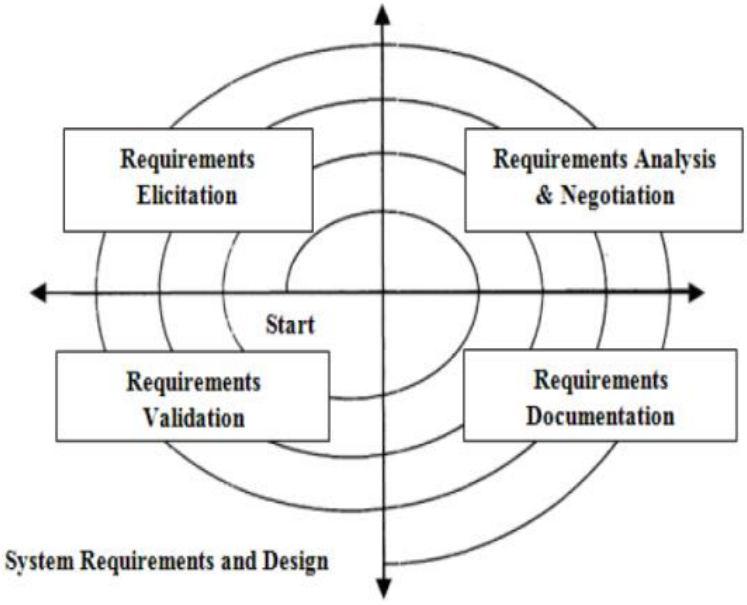

Figure 4 Spiral Model of Software Development (Boehm, 1995)

Qualitative interviews were divided into four phases, after each phase the collected data was analyzed and requirements were extracted. These preliminary requirements ware then used in successive phases, which were more targeted and the focus was shifted to discovering new needs and requirements. The successive interviews also served the purpose of validating and evaluating the already gathered requirements, which represented what the new system would be like. The process was repeated until a refined set of feasible requirements were defined.

Data Analysis

Scientific literature, journal articles, and text books were used as the source of material during literature review. The data analysis in the literature review was used for categorization and summarization to combine and construct important topics in case company's context. Documentation review regarding processes and work instruction was done to develop an understanding of the current state of the processes.

Qualitative interviews, all except one of which were recorded, were then transcribed. The transcripts of the interviews were then studied and analyzed to identify the emerging patterns. Responses related to similar issues were highlighted with different colors and then these responses were used to drive the requirements, or identify the opportunities where digitalizing would bring improvements. After each phase of the interviews, data was analyzed and preliminary results were developed.

These results were then used in the proceeding interviews for validation of the defined requirements by the users themselves. This helped ensure that every derived requirement does indeed represents a user need. After the first phase of interviews, subsequent interviews were also used to assess the perceived benefit of having certain features in the system, this information assisted in prioritizing the requirements.

Finally, once all the interviews were complete the final requirements seemed to be falling into specific groups, which are presented in Chapter 6 as the business requirements. Using the extracted business requirements and the logical sequence of activities, the use cases were developed to better communicate the requirements. Visual representations of the use cases also helped in developing a clear understating between users and requirements developer (researcher) about how the user intends to interact with the system. The initial versions of the use cases were shared with some of the interview participants to get the feedback and the suggested modification were then made.

1.4 Structure of the Thesis

The structure the report is shown in Figure 7, thesis is divided into four parts; motivation, research context and case company, and research methodology is presented in Chapter 1. Second part consists of a literature review; EPC/EPCM projects are introduced in chapter 2 along with the description of the construction industry supply chain. Chapter 3 presents a detailed discussion on supplier relationship management. Chapter 4 discusses types and categories of requirements, requirements elicitation and development processes. Chapter 5 presents the conceptual framework for the thesis.

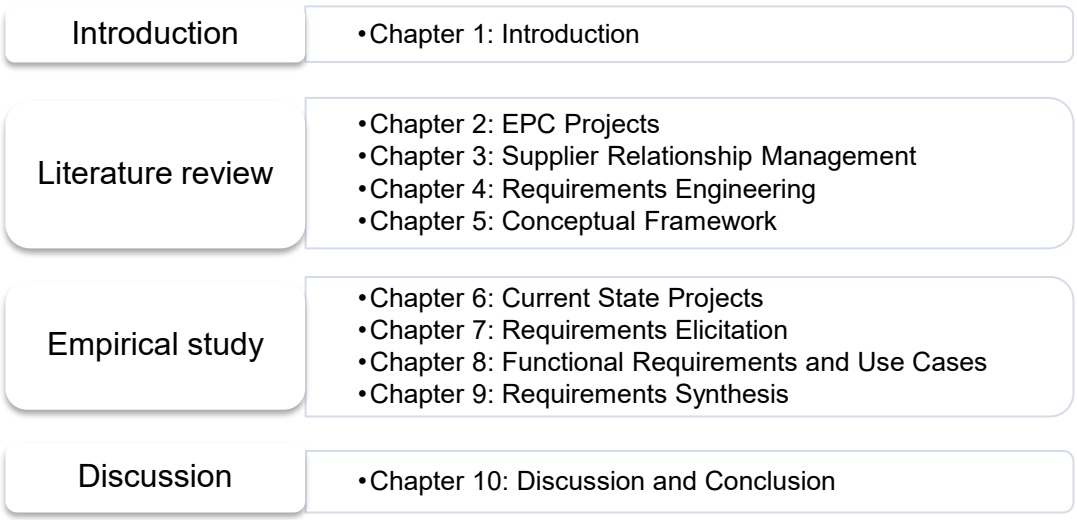

Figure 5 Structure of the thesis.

Part 3 consists of the empirical study; Chapter 6 presents an overview on the current state. In Chapter 7, results of the interview are discussed and system requirements are presented, Chapter 8 illustrates the functional requirements with use cases and in Chapter 9, prioritization of the requirements is presented along with recommendations for implementations. Finally, the last part, Chapter presents the discussion on the results and conclusion.

2. ENGINEERING PROCUREMENT AND CONSTRUCTION PROJECTS

In Chapter 2.1 different phases of an EPC project for building a process facility are presented. In Chapter 2.2 the difference between EPC and EPCM contracts is explained, Chapter 2.3 presents different aspects of construction industry supply chain and in Chapter 2.4 differentiating characteristics of construction industry supply chain are explained.

2.1 Stages of a Typical EPC Project

An EPC project has several phases; conceptual study, Front end engineering design (FEED), detailed engineering, procurement, construction, commissioning and start-up. These stages are further described in this section. EPC projects in the process industry are generally longer-term projects and it can take up to five years or more to make a new processing facility. Figure 8 shows the phases in EPC project for building a process facility (Aronen, 2015).

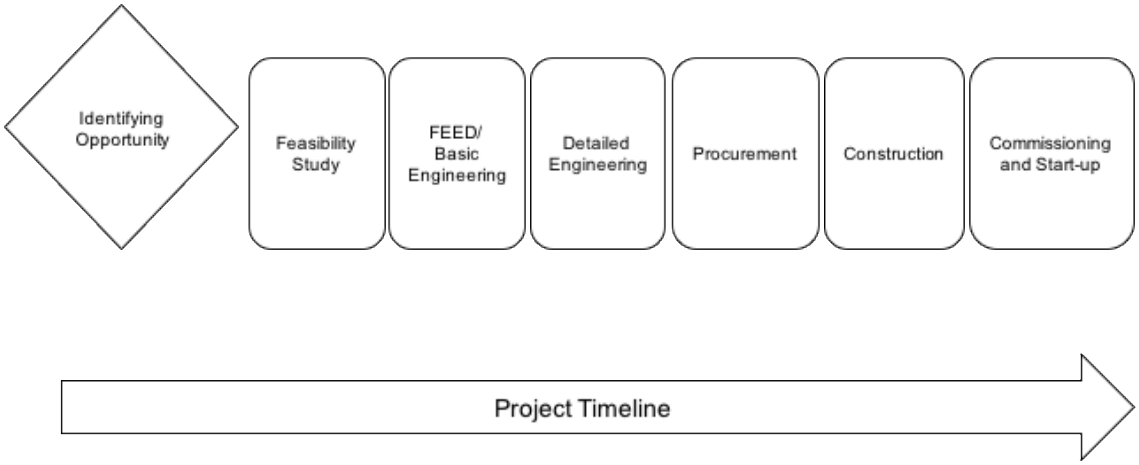

Figure 6 EPC Project Phases for a Processes Industry Facility (Aronen, 2015).

Identifying Opportunity

Before the investment plan for a facility begins, business study is developed. The purpose of this activity is to define business opportunity, cost estimations, and investment plan schedule along with the technical assessments. The result of a business study is the economic evaluation and functionality requirements for the project. (Baron, 2015)

Conceptual Design

Every investment plan for a new processing facility starts with the feasibility study, also called conceptual design. Feasibility studies are conducted in the initial phases of the project in order to assess the profitability of the investment project. Feasibility studies are usually conducted through surveys, data gathering, and analyzing the whole environment around the project. This can include legal requirements, Government policies, financial market situation, tax regulations, industry analysis, suitable production processes and equipment, investigation and calculations of process equipment configurations, and operating costs. Preliminary Hazard and Operability study (HAZOP) is also conducted to assess the planned processes and operations in order to identify and examine potential issues that pose risk to personnel, equipment or environment. Feasibility studies evaluate the potential success for the project and provide information on which investment decisions can be based.(Nguyen, 2017)

Front End Engineering Design

Once the conceptual study for the project has been completed, project moves forward into the front-end engineering design (FEED), also called the basic engineering sometimes. In this phase of the project, the focus is on defining technical requirements and calculating investment costs for the project. FEED can be split into various packages, which cover different parts of the project. These FEED packages are used to finalize the project technical scope and sufficient cost estimations, this information provides the basis for bidding process and execution phase contracts. Sometimes vendors are requested to provide the budgetary quotation, EFFD contactor may also use existing price lists by the vendors. Final investment decision is made after Front end engineering design is complete. (Nguyen, 2017)

Engineering

The engineering phase follows FEED, it is also called the execution phase of the project. At this stage project engineering companies start bidding for the project packages, and vendors prepare first quotations for the engineering companies. Awardee of the project contract carries out the detailed engineering design for the project, procurers all the needed equipment and materials, and then constructs the facility to deliver functioning plant to the owners. Firms that deliver engineering procurement construction projects are usually referred to as the EPC contactors. Sometimes, the same company can deliver FEED and act as the EPC contractor also. For the larger projects, many EPC contactors are involved in different project packages. (Nguyen, 2017)

Procurement

The procurement organization for an EPC contactor connects the engineering and construction. Procurement includes; the sourcing of materials and equipment within the budgetary requirement, controlling production process after order placement, quality control and inspections, and transportation of goods to the project sites according to the project schedule. The procurement department is responsible for sourcing suppliers, purchasing, expediting, inspecting the manufactured equipment and bulk material, and arranging delivery and logistics support as well. Procurement offices can be located anywhere, this provides more efficient use of procurement resources for the project contractor. (Nguyen, 2017)

Construction

The construction work includes mechanical equipment installations, piping, electric and instrument system installations, underground and aboveground structure framing, installations, painting and all other construction related activities. Any project involves many different contactors and thousands of workers performing work at the construction sites. Construction sites can be situated in extremely cold regions to deserts, it is the responsibility of the construction organization to insure the site standards and regulations for the labor, health, safety and environment requirements are carefully followed in all the construction activities. (Nguyen, 2017)

Commissioning and Startup

After the construction work has been completed, the commissioning of the plant is performed before going into commercial operations. The purpose of commissioning and start-up is to verify that the facility operates according to the design and project specifications. The success of startup requires planning and participation of all the stakeholders; engineers, suppliers, construction, owners, and startup team. Deep understanding and analysis skills are you needed for troubleshooting in the commissioning and startup phase. Completion the delivery of a well-designed and safe facility requires effective commissioning and startup planning. (Nguyen, 2017)

2.2 EPC vs EPCM Contracts

2.2.1 Engineering, Procurement and Construction Projects

EPC projects, sometimes also called “Turnkey” projects, are the contacts where the owner makes a single contact with the EPC contractor to design and build a plant or a facility. These contacts are usually fixed-priced lump sum contacts, where EPC contactor executes most of the work with relative freedom. The client usually has less say in the design, and

contractor bears more risk (Plummer, 2007). A typical EPC contract arrangement is shown in Figure 9.

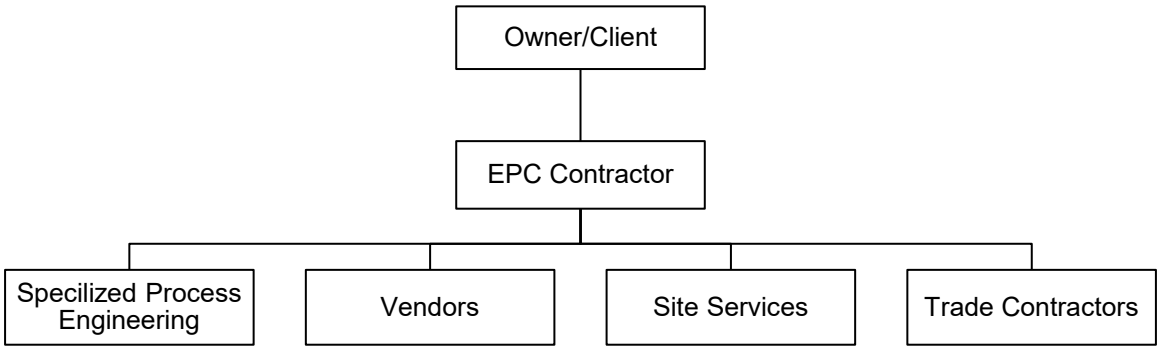

Figure 7 EPC Contract Arrangement (Plummer, 2007)

The EPC contractor makes direct contracts with vendors and subcontractors, and is responsible for all the engineering, procurement, construction, project management, and delivering a commissioned facility to the owner. The EPC contractor may or may not be the FEED contractor. Figure 10 shows the role of EPC contractor and client (owner) in the projects.

<table>
<tr><td></td><td colspan="4">Project Components or Subprojects</td></tr>
<tr><td>Phases</td><td>Civil & Foundation</td><td>Plant</td><td>High-Tech Equipment</td><td>Offsite Utilities</td></tr>
<tr><td>Client Project Management</td><td colspan="4">Project Management Team (PMT)</td></tr>
<tr><td>FEED</td><td></td><td>FEED Contractor</td><td></td><td></td></tr>
<tr><td>Project Management</td><td colspan="2" rowspan="5">EPC Contractor</td><td rowspan="5">High-Tech Proprietary Equipment Supplier</td><td rowspan="5">Client PMT</td></tr>
<tr><td>Engineering</td></tr>
<tr><td>Procurement</td></tr>
<tr><td>Construction or Manufacturing</td></tr>
<tr><td>Commissioning</td></tr>
<tr><td>Start-up</td><td colspan="4">Client Start-up Team</td></tr>
</table>

Figure 8 EPC contract arrangement (Plummer, 2007)

High-tech proprietary equipment is usually procured as packages from the suppliers. EPC contactor sources all the equipment and makes contracts the suppliers of package deliveries. Sourcing all the other equipment, materials, and subcontractors, is the responsibility of the EPC contractor as well.

2.2.2 Engineering Procurement & Construction-Management Projects

Another common contracting strategy is engineering, procurement and construction management (EPCM) contracts, these contacts are more like professional services contracts. In these type of contracts, EPCM contractor assists the client in bidding, supervising, and administering the construction. The client selects the contactors for different work packages at the advice of EPCM contractor, while retaining control on the construction phase. EPCM contractor is not liable for any of the work packages by the subcontractors and the client is directly involved with the suppliers (Plummer, 2007). Figure 11 shows the organizational model of a typical EPCM contract.

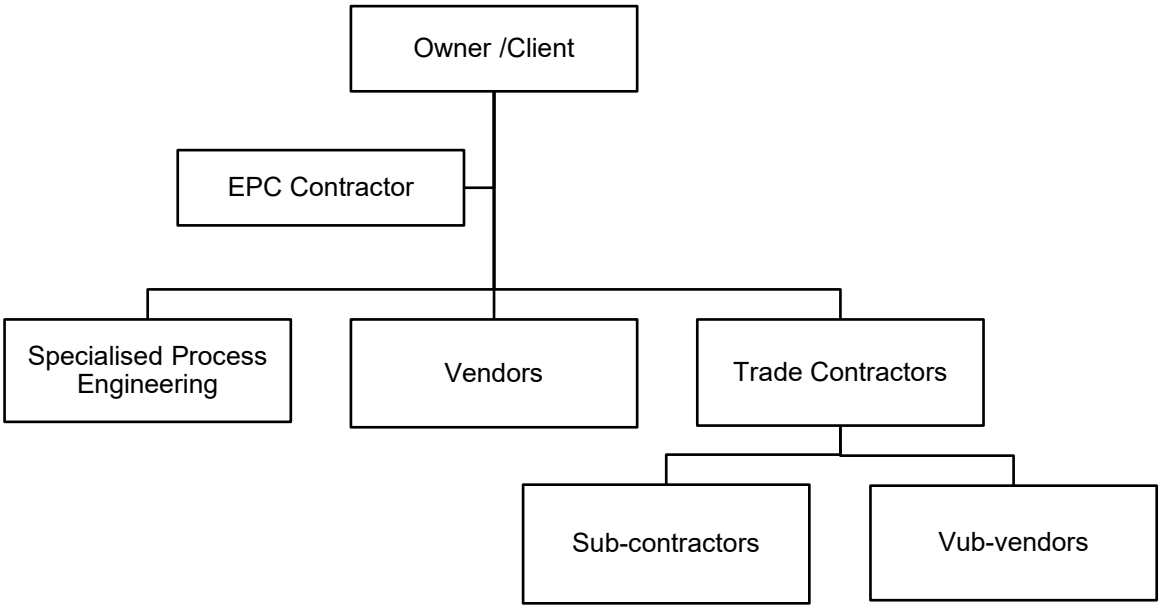

Figure 9 EPCM Contracting Strategy (Plummer, 2007)

These types of contracts are preferred by the clients when they want a higher degree of involvement in the project, however, they lack the necessary experience and personnel to manage the projects on their own. Client and the EPCM contractor establish integrated management teams for different phases of the project; FEED, Detail Engineering, Procurement, Construction or Manufacturing, Commissioning, and Project Management. (Plummer, 2007) Figure 12 shows the client's and EPCM contractor's roles in different phases of the projects for different components.

	Project Components or Subprojects			
Phases	Civil & Foundation	Plant	High-Tech Equipment	Offsite Utilities

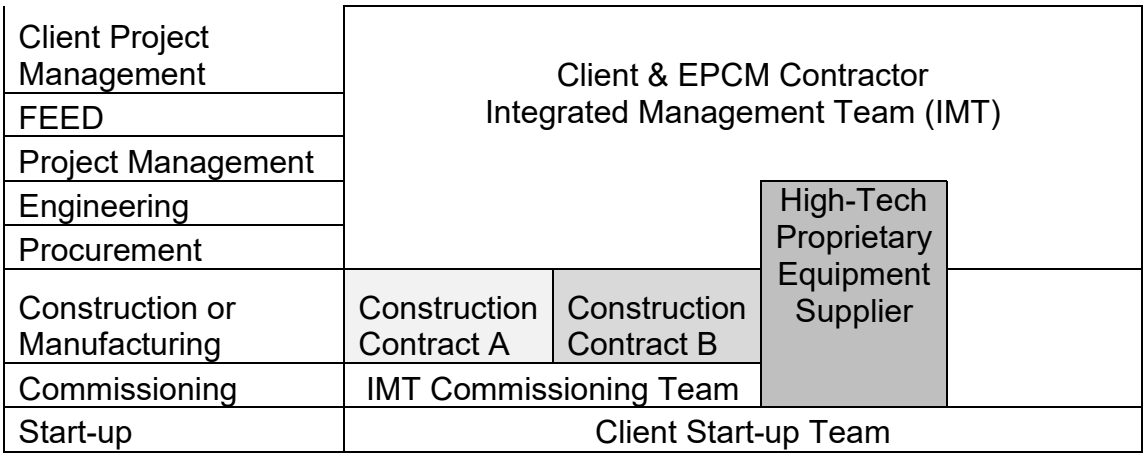

Figure 10 EPCM contract arrangements (Plummer, 2007).

2.3 Construction Industry Supply Chain

Supply chain in the construction industry has various special characteristics and differs significantly from that of manufacturing industry. Construction firms deliver one-off products as projects, this practice makes construction industry unique (Cox, Townsend and Ireland, 2006) and therefore the definition of construction supply chain is different from the manufacturing industry supply chain. According to Muya et at., (1999), there are three kinds construction supply chains:

- The Primary supply chain: this delivers the materials which are utilized in the final construction of the product.
- The Equipment supply chains: this delivers equipment, expertise and the materials for facilitating the construction.
- The Human-Resource supply chain: this is concerned with the supply of labor and human resource.

The supply chain concepts depend on the processes within the industry, the schematic view of the operational activities in the construction industry is presented in Figure 13 (Edum- Fotwe, Thorpe and McCaffer, 1999).

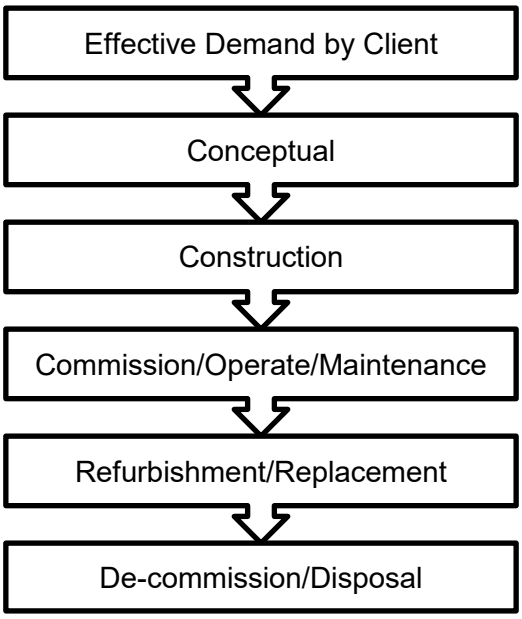

Figure 11 Operational activities in the construction industry (Edum- Fotwe, Thorpe and McCaffer, 1999).

The process shown in the above figure is presented as a chain and could be cyclical sometimes, whereby multiple repetitions are performed as the facilities are modernized, upgraded or replaced; or it can terminate in cases where many one-off private developments are done (Edum- Fotwe, Thorpe and McCaffer, 1999). Based on the research, Cox and Ireland (2001), have suggested a typical construction supply chain shown in Figure 14.

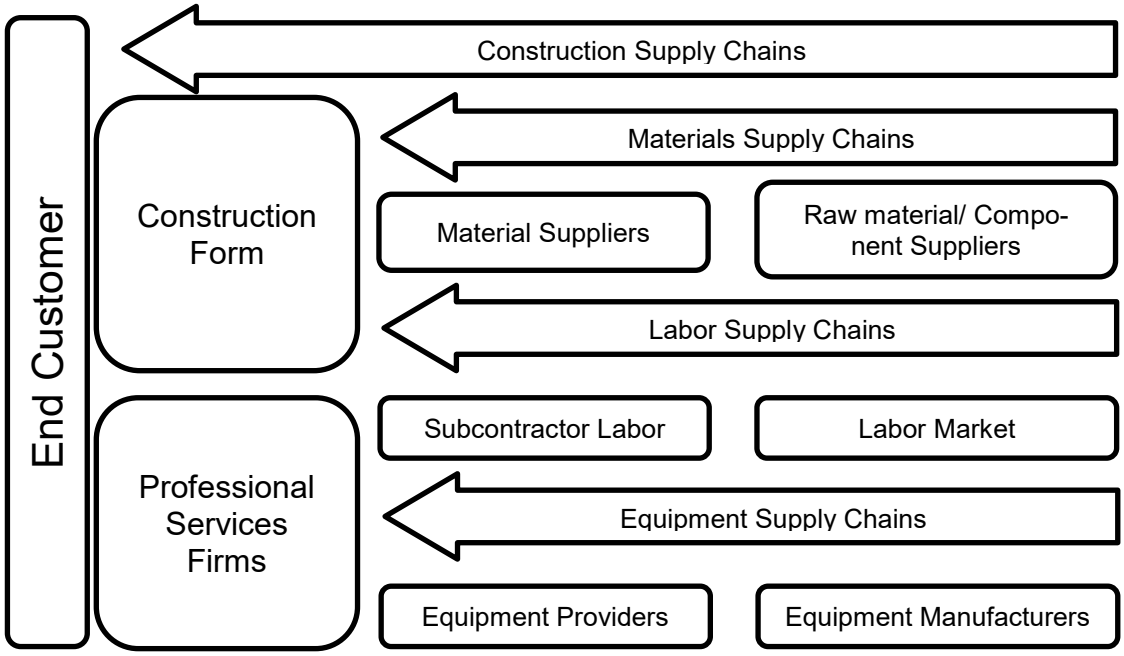

Figure 12 Construction industry supply chain (Cox and Ireland, 2001).

As shown in the figure above, the “end customer” represents all the customers of the construction project. Clients usually source the construction projects from construction supply markets in order to get the required functionalities from the project to support the business (Butkovic Lovrencic, Kauric Grilec and Mikulic, 2016). Moreover, the “construction or civil engineering firm”, shown in the picture above, includes all the firms that are responsible for delivering the project to the end customer. These firms operate as integrator for all the constituent supply chains and coordinate the whole chain. “Professional services firms” cover all the engineering, designing, planning services providing firms.

One of the major features of the construction supply chain is that each of the clients signifies a unique customer which has its own unique requirements, and construction supply chain must adapt to those requirements in order to be more efficient and effective (Cox and Ireland, 2001).

2.4 Characteristics of Construction Supply Chains

Although processes in the construction industry differ significantly from that of manufacturing industry, supply chain management practices are still useful and effective in construction industry (O’Brien, 1999). Supply chain management can be a favorable approach to achieve a successful integration of internal and external suppliers, designers, contactors, sub-contractors, and other internal and external clients.

In order to analyze the supply chain management in construction industry, the distinctions between a “construction product” and a “manufactured product” must be specified. Since both of these products are characteristically different, therefore, supply chain management principles cannot be applied the same way in both domains. Some of the critical distinctions between products in the manufacturing industry and in the construction industry are given below (Papadopoulos *et al.*, 2016)

- Products are always delivered as projects.
- The product as the result of each construction project is different.
- Usually, a construction project is intended for a single client.
- The Place, equipment, and methods of production differ in each project.
- There is a high personnel rotation index in construction projects.
- All the parts and materials cannot be stored at the production site.

With regard to the structures and functionality of construction supply chain, Vrijhoef and Koskela (2000) has mentioned the following characteristic elements:

- It is a converging supply chain, where all the materials and equipment from suppliers are directed to the construction site. The "construction factory" is established around the product where the incoming materials are assembled. In contrast to the manufacturing, where numerous products are produced in the factory and distributed to multiple customers.
- Apart from some exceptions, it is a temporary supply chain which produces one-off construction projects by repeatedly reconfiguring project organizations. As a result, construction industry is characterized by fragmentation, instability, and separation of the design and construction of the product.
- It is made-to-order supply chain, where every project creates a different product. The process can be quite similar for specific kind of project, however there is little repetition in the products.

All these aspects have to be taken into account when analyzing the supply chain and supplier relationships in the construction industry.

3. SUPPLIER RELATIONSHIP MANAGEMENT

In Chapter 3.1 definition of supplier relationship management is discussed, different classification models for supplier relationships are discussed in Chapter 3.2. Benefits of SRM are discussed in 3.3 and Chapter 3.4 presents activities involved in the supplier relationship management process.

3.1 Definition

Gartner Consulting (2001) define supplier relationship management as “a set of methodologies and practices needed for interacting with suppliers of products and services of varied criticality to the profitability of the enterprise”. Developing this further Poirier (2006) defines it as “a means of making closer relationships with selected suppliers, with the purpose to discover the added features that could enhance the relationship while improving business performance as the firms work in an environment of mutual benefit and increase the likelihood of creating profitable new revenues together” (Poirier, 2006 p. 3). Fogg (2009) has focused on the interactive aspects of the relationship between the supplier and buyer and on the benefits of improved performance to both parties as well. According to him, SRM is “the process of managing the interaction between two entities - one of which is supplying goods, works, or services to the other entity”. He has further described SRM as "a two-way process in that, it should improve the performance of the buying organization as well as the supplying organizations and hence be mutually beneficial” (Fogg, 2009). It also supports Brimiacombe et al.’s view (2011) that SRM can “optimize value through cost reduction, innovation, risk mitigation and growth throughout the relationship life cycle”.

Management consulting firms also contributed in developing the SRM terminology. PricewaterhouseCoopers (2013) has emphasized the value of the two-way relationship between buyers and suppliers. However, PwC has emphasized on the relationships with key suppliers, the mutual benefits that both parties can achieve, as well as the characteristics of these relationships. PwC simply defines SRM as “a systematic approach for developing and managing partnerships, focused on joint growth and value creation with a limited number of key suppliers based on trust, open communication, empathy and a win-win orientation”(PricewaterhouseCoopers, 2013).

SRM can contribute to a company’s competitive advantage when it is taken into consideration across the organization (O’Brien, 2014). Schuh et al. (2014) took a similar and more holistic approach to SRM, he has introduced the term “true SRM”, here SRM is

supposed to “drive supplier’s behavior, encompass the relationship between two enterprises and enable a company to leverage its size by coordinating across divisions, functions, and hierarchies” (Schuh *et al.*, 2014).

It can be seen that various definitions are present in the academic literature for the term supplier relationship management; nonetheless, most of the definitions posit “developing and managing relationships and interaction between suppliers and buyers” as an important point of supplier relationship management. Moreover, all of these illustrate that good supplier relationship management will create a win-win relationship and help create value for both parties.

3.2 Benefits of SRM

The goals of SRM and the benefits it can bring to an organization are discussed a lot in the academic research; this section is meant to examine some of the benefits in more detail.

Many of the research studies have shown a strong relationship of a successful SRM to the financial performance of a company (Carr and Pearson, 1999; Johnston *et al.*, 2004). In a study presented by Schuh *et al.*, (2014), SRM is said to have affected supplier performance, risk management, supplier segmentation, improving communication across functions, and hierarchical levels. Moreover, a strong relationship with the supplier can enhance its performance like; lower lead time (Larson and Kulchitsky, 2000), higher responsiveness and loyalty to the buyer (Martin and Grbac, 2003).

Another benefit of SRM was pointed out in the research by Gartner Consulting (2001), SRM can optimize relationships with the suppliers because each supplier is treated differently based on the value provided. Most significantly, supplier relationship management starts the development stretching beyond the contractual agreements and maximizes the value across supply chain (Schuh *et al.*, 2014). Schuh et al. also state that SRM can enable a company to utilize its supplier base to gain a competitive advantage. In wider perspective, the aim of SRM is to work together with the supplier base to create an ecosystem that contributes towards a company’s competitive advantage. Moreover, going beyond the cost optimization to pursue a strategy of growth and innovation (Johnston *et al.*, 2004; Schuh *et al.*, 2014). Research by Gartner Consulting, (2001) also supports these views, it adds that SRM can speed up the introduction of innovative solutions to the market by working together with the suppliers. It can reduce the cost of supply chain and operations and derive the profits while still ensuring the quality.

In addition, PwC (2013) emphasizes the importance of joint development and investments in SRM because of the common goals, combined efforts, and resource commitments, thereby creating a culture of continuous advancement. According to them, it en-

courages supplier's behavior and capabilities since suppliers stand to benefit through involvement in early stages of development. Because of that, both buyer and supplier have a joint commitment and enjoy equal success (Lambert and Schwieterman, 2012). Therefore, these advantages make the buyer a preferred customer with better access to supplier's resources. Eventually, SRM strengthens the buyer supplier relationship and increases the prospects for future cooperation (Duffy and Fearne, 2004) and improves performance of the supply chain (Benton and Maloni, 2005; Narasimhan and Nair, 2005). It is quite evident from the presented discussion that SRM can play an important role for a company by reducing costs, driving profits, and by establishing good relationships with suppliers.

3.3 Classification of Supplier Relationships

Academic literature describes different types of supplier-buyer relationships, even though by all supplier relationship is quite important; however, all the relationships are not equal (Trent, 2005). Various frameworks have been developed to categorize the supplier relationships based on the value they add to the buying organization. Some of these models are described here in detail. Trent (2005) presented the four C's of buyer-supplier relationships as shown in Figure 15. According to him, buyer supplier relationship can be categorized into four classes: *counter-productive (lose-lose), competitive (win-lose), cooperative (win-win), and collaborative (win-win)* (Trent, 2005). The following description is based on the studies of Trent (2005) and Zamboni (2011).

Counterproductive (Lose-Lose)	Also called antagonistic relationships	Work actively against each other's needs	Neither party takes responsibility for what happens in a relationship	Destructive conflict occurs
Competitive (Win-Lose)	Also called adversarial or distributive relationships	Engage in a Competitive struggle to divide a fixed amount of value	Attempt to maximize value for each side	Minimal sharing of information
Cooperative (Win-Win)	Also called Integrative relationships	Longer-term Relationships result from mutual goals	Supplier Involvement during product development increases	Open sharing of Information occurs, including sharing of cost data
Collaborative (Win-Win)	Also called integrative or creative relationships	Congruence of goals and co-destiny exists	Jointly identify new market opportunities	Jointly identify creative solutions to problems

Figure 13 Classification of supplier relationship Trent (2005) and Zamboni (2011)

Counter-productive relationships are the outcome of both parties working against each other, resulting in no profit for either. This competitive relationship is an adversarial relationship, where members work towards their own objectives to gain a bigger share of the value. The cooperative relationships are formed when suppliers are a part of the long-term strategy of the company for the supply-base. These relationships are bound to long-term agreements and characterized by the combined efforts for reducing costs, improving quality and other issues related to developing a more efficient supply chain. Finally, the collaborative relationships are usually established with only some specific suppliers, who supply goods or services of critical nature. Buyers and suppliers work jointly on development activities in this type of relationship. Collaborative relationships are also termed "strategic alliance" by some researchers (Leenders *et al.*, 2006).

Cox (2004) has presented a model to categorize supplier-buyer relationships in a two-dimensional area of interaction. Figure 16 shows Cox's model.

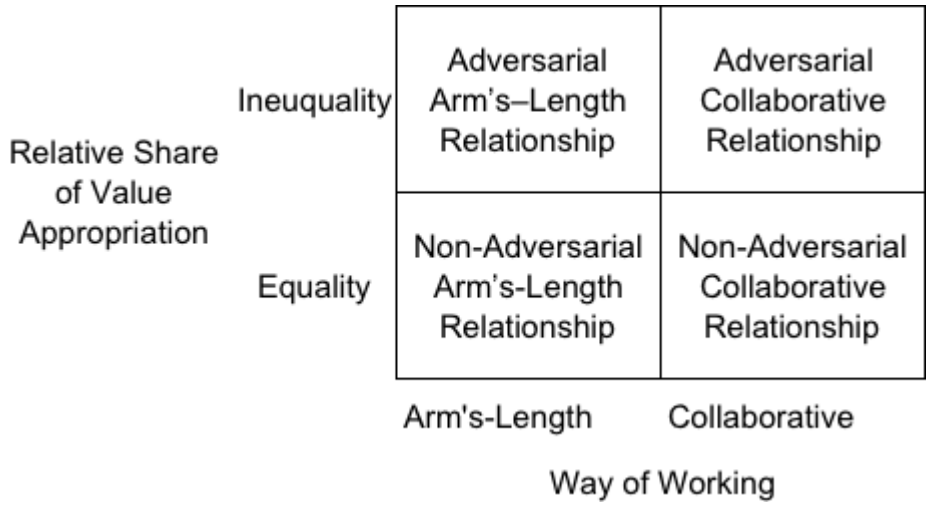

Figure 14 Supplier classification Cox (2004)

According to the model presented by Cox and Ireland (2002), one aspect is the "*way of working"*; it is the operational interaction between organizations. The other aspect is the "relative share of value appropriation", meaning how partners try to maximize their relative share of the value. Only a limited amount of information exchange takes place when companies keep each other at arm's length. Their research also indicates that more collaborative interaction takes place when both parties are invested in developing a long-term relationship and share the business goals and values. Ha *et al*.'s (2011) work shows that if partners try to maximize their own share and disregard the other party, this results in an adversarial values-appropriation. In contrast, when each party tries to develop a win-win relationship by sharing the value with the other, it is called *non-adversarial value-appropriation* (Ha, Park and Cho, 2011).

From these two characteristics, four distinct styles for supplier relationship management have arisen (Cox, 2004). These relationship styles are quite similar to the ones presented

by (Trent and Monczka, 2003). In line with his model; four styles described by Cox (2004) are given in Table 2:

Table 2 Types of supplier relationship Cox (2004)

Type of Relationship	*Description*
Adversarial arm's length	Short-term transactional indirection with exchange partner aiming to maximize to maximize its share of the value
Non-adversarial arm's-length	Exchange partner paying the running market price without strong bargaining
Adversarial collaboration	Exchange partner shares the operational and its relationship-related information with the suppliers but still wants to optimize its share of the value
Non-adversarial collaboration	Exchange partner aims to build long-term relationship by working transparently and sharing value equally.

Peter Kraljic (1983) developed a traditional framework which is depicted in Figure 17 , Kraljic's model is more focused on the potential profit impact and possible supply risks from the suppliers, rather than the value generated for buyers and suppliers from the relationship (Gelderman and Semeijn, 2006).

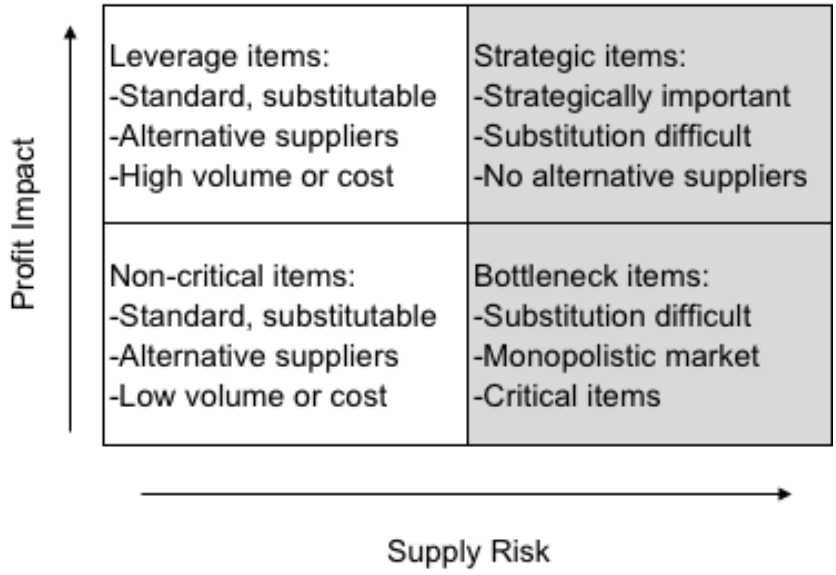

Figure 15 Peter Kraljic's (1983) portfolio matrix.

In Kraljic's portfolio matrix, products are categorized by high-low supply risk and high-low profit impact. This results in four different product categories: Strategic, Bottleneck, Leverage, and Non-critical items. Suppliers providing these four categories of items can

be assigned to these groups (Nellore and Soderquist, 2000). Strategic and bottleneck suppliers, from these four categories, demand the most attention from companies. Whereas, suppliers of non-critical or leverage items can be managed with lessor efforts (Gelderman and Van Weele, 2003). It is noticeable that strategic relationship is similar to the collaborative relationship presented by Trent (2003), strategic alliances in Leender's study (2006) and non-adversarial collaborations of Cox's model. Although, the rest of management styles are not congruent to the categories of other described models, Kraljic's model provides a different aspect by considering the nature of the product for classification of relationships.

From the discussion of these models, it can be drawn that for buyer's relationship with suppliers differ in nature. These models inform organizations how to classify the suppliers based on the strategic value of their products or services to choose the most suitable relationship type and managerial approach.

3.4 Supplier Relationship Management Processes

Supplier relationship management is already a complex concept to understand, and it is even more difficult to for companies to decide how they can manage relationships with their suppler base (Cox, 2004) the best way. Nevertheless, (Trent, 2005) suggests that there are some SRM practices that organizations can focus on. The following part describes in detail supplier relationship management activities. These include:

Supplier Selection

Some academics consider suppliers selection a part of supplier relationship management (Liker and Choi, 2004; Park *et al.*, 2010) and it is crucial for an efficient manufacturing operation and supply chain. Buyers usually have a number of suppliers available to them, the most important thing here is to select a supplier that offers the best value, cost, and functionality mixture (Cox, 2004).

Suppliers are assessed against set criterion before selection or rejection. This process is critical, as it provides the bases for the entire supplier management process latter on. There are certain difficulties buyers must address: single sourcing and multiple sourcing. In single sourcing, all the sourcing requirements of the organization are to be met by a single supplier, this demands the sourcing manager to be very careful in selecting the most suitable one. When sourcing requirements cannot be met by only one supplier, managers need to choose several suppliers and carefully distribute the supplies among them (Park *et al.*, 2010).

Organizations need to consider multiple factors in the supplier selection process (Handfield, Monczka and Giunipero, 2011). Leenders *et al*., (2006) states that financial health, location, technological capability, and quality system are important factors. The relative size advantage that buyer enjoys over a supplier is also a key factor, because it affects the bargaining power of the buyer. Therefore, based on the size and business needs, buyer can decide it would have a size advantage or not. Buyer enjoys a stronger position in the negotiation if it represents a bigger portion of supplier's business. (Handfield, Monczka and Giunipero, 2011)

Lysons (2000) has also indicated some other important issues that should be considered in the selection suppliers such as local or global suppliers, competitors as suppliers, and low-cost sourcing. Therefore, companies must establish some clear criteria taking into consideration business needs and position when choosing suppliers.

Supplier Evaluation

Supplier evaluation is important in managing suppliers-buyer relationships. Supplier evaluation is done at two stages; suppliers' selection, and supplier development. In supplier selection phase, supplier evaluation is carried out to prioritize the potential suppliers in order to select the most suitable one. In the supplier development process, supplier evaluation is used to control and evaluate the suppliers-buyer relationship (Osiro, Lima and Carpinetti, 2014).

Supplier evaluation in the supplier relationship management is "the process of quantifying the efficiency and effectiveness of supplier actions" (Neely *et al.*, 1997). Supplier evaluation process assists the decision-making process of the buying company, through this, buying organization can implement changes or encourage improvements in supplier's behavior (Neely *et al.*, 1997). Moreover, it is also a way to affect supplier's actions (Schmitz and Platts, 2003).

Evaluation is not strictly defined in the academic literature and can refer to various activities in the process. Hald and Ellegaard (2011) describe evaluation in a three-phase model, which is primarily related to supplier's performance evaluation. According to them, supplier evaluation is the process of evaluating supplier's performance and the performance measurement guides further action. Some authors think of evaluation as the segmentation and classification of suppliers against a set criterion (Olsen and Ellram, 1997; Araz and Ozkarahan, 2007). Thus, in addition to the performance evaluation, supplier segmentation should also be taken into consideration in the evaluation process.

Supplier Segmentation

As explained in the previous section, some authors consider supplier segmentation as part of the supplier evaluation process (Olsen and Ellram, 1997; Araz and Ozkarahan, 2007). Nonetheless, this section explains the supplier segmentation separately to explain the objectives and activities in more detail.

Svensson (2004) consider supplier segmentation an important activity for company's business, as it can support company's efforts to improve and sustain the market position among other strategic objectives. Segmenting the supply base guides the direction of buyer-supplier relationships (Day, Magnan and Moeller, 2010). According to them, through supplier segmentation, companies are more able to evaluate suppliers by taking into account the past collaborations, potential abilities of the value generation, and prospective future partnerships. Therefore, supplier segmentation can be vital in linking firm's capabilities to draw best value from the supplier base (Day, Magnan and Moeller, 2010).

Kraljic's model, as explained earlier, is considered a major breakthrough in purchasing history to rank suppliers (Svensson, 2004). In his model, suppliers are classified based on supply risk and profit impact. There are many other models developed after Kraljic's model such as; in the study of Olser and Ellarm (1997) and Araz and Ozkarankan (2007). Suppliers are classified based on two aspects in most of these models. In the framework presented by Olser and Ellarm (1997) suppliers are placed in different groups based on the performance and strength of that relationship. PwC (2013) has categorized suppliers according to "competitive advantage and business fit" versus "performance at risk", in this framework suppliers are classified as preferred, transactional, strategic or development suppliers.

In a different approach, Lamming (1994) mentioned multiple tiers of suppliers namely; first, second, and third tier suppliers. This distinction represents the degree of influence a supplier can have on the supply chain. Suppliers with an integrated system for supplying directly to buyers or those who could significantly impact the buyer if they supplied indirectly are considered first tier suppliers. The second-tier suppliers deliver support services or generate inputs to the first-tier suppliers (Lamming and Rand, 1994)

Due to the presence of many models for segmentation, PricewaterhouseCoopers (2013) suggests there organizations should take into consideration the most important aspect for them such as; corporate strategy, industry specific requirements, business processes among others, for the supplier segmentation process.

Relationship Development

Relationship development differs from supplier development; it is a reciprocal interaction between parties and is focused on the relationship instead of the delivery of products or services (Fogg, 2009). While, the supplier development process is more on the tactical level and is primarily focused on solving problems, relationship development starts from an already good existing relationship between parties. Fogg defines relationship development as "a two-way process between buyers and sellers where activities jointly undertaken bring the organization and the people working within them progressively closer towards a more trusting and mutually beneficial state". (Fogg, 2009)

The (Ford, 1980) has emphasized a great deal on the human element of organization, in order to better tackle the relationship management. Human investment from the beginning of the relationship is quite beneficial to relationship development (Paulraj, Lado and Chen, 2008). Firms should encourage the suppliers to give their ideas in the development process (Trent, 2005) and there should be effective inter-organizational communication. Buyer's personnel should also understand supplier's employees, what their aspirations are and where they would like to lead the organization to (Fogg, 2009). Furthermore, according to Liker and Choi (2004) and Fogg (2009), to have a more frequent updates and information, exchange regular meetings between people from both organizations should be held. This will also help engage people from organizations with each other. Moreover, Mentzer Jr, Myers and Stank (2007) and Ford (1980) point out that a long-term commitment and trust is required in order to foster a good relationship between suppliers and buyers.

Performance Measurement

Performance measurement is a standard way to review and control supplier performance in a systematic manner (Handfield, Monczka and Giunipero, 2011). It provides information for the organization that is useful in planning and managing different activities in the organization (Cousins, Lawson and Squire, 2008). According to (Handfield, Monczka and Giunipero, 2011) performance measurement evaluates qualitative factors such as delivery issues, quality standards, and cost comparison. Various authors have suggested different ways to measure supplier performance such as; the balanced scorecard by Kaplan and Norton (1996) or the performance pyramid by Cross and Lynch (1992).

One purpose of measuring supplier performance is to inform the decision-making process (Olsen and Ellram 1997), and encourage supplier behavior better suited to company's

goals. Most importantly, measurement results can motivate suppliers direct their activities and behavior (Leenders *et al.*, 2006). Buying organization also need to measure because they have to ensure the supplier performance is according to the agreement, it helps in identifying possibilities for improvement and point out shortcomings from of the both parties (Fogg, 2009).

Deciding what should be measured is an important part of the process; buyers have various qualitative and quantitative factors that can be measured. Fogg (2009) suggests that companies should measure what they believe to be the most important for them, particularly taking into account the strategic goals of the organization. According to Handfield et al. (2011) following sectors are most common:

- Time/ delivery/ responsiveness
- Technological feasibility
- Quality performance
- Cost effectiveness
- Strategic performance
- Technological innovation
- Sustainability and environmental safety

There should be specific measures for each of these categories, either objective or subjective (Handfield, Monczka and Giunipero, 2011). For example, difference in actual delivery and agreed delivery dates can be used to evaluate delivery performance (Beamon, 1999), defective parts for a defined quantity can be used as a quality performance parameter (Benton, 2010). Moreover, quality audit can be performed to evaluate the quality management system of the suppliers, these can significantly affect performance measurement results overall. Therefore, organizations need to develop performance measurement systems with clarity, defined objectives, available data and more importantly with participation of both buyers and suppliers (Globerson, 1985; Neely *et al.*, 1997). PwC (2013) has suggested adopting a two-way measurement strategy, where buyers and suppliers both evaluate each other's performance. This practice will encourage cooperation and increase effectiveness for performance measurement, as both parties will commit to the performance parameters (PricewaterhouseCoopers, 2013).

Kaplan and Norton's (1996) research suggests the use of balanced scorecard, PricewaterhouseCoopers, (2013) also support this method of track the performance measurement process overtime. Balanced scorecard is based on value drivers for performance control and enhancement. Balanced scorecards include elements such as operational, financial as well as other external and internal aspects (Handfield, Monczka and Giunipero, 2011). Organizations should also integrate development capabilities into the scorecards; this can be useful in driving performance in the future (PricewaterhouseCoopers, 2013).

Risk Management

Supply chains have evolved into complex supply networks which are not only complicated but also extremely sensitive to risks (Hallikas *et al.*, 2005). According to them, it is the result of global sourcing, increased customer demand, and growing complexities for products. Because of these factors, organizations are more vulnerable to the risks stemming from external sources. Therefore, it is crucial to focus on supply chain risks and uncertainties involved in sourcing operations. (Hallikas *et al.*, 2005)

Supply chain risks differ in different parts of the chain, Johnson (2001) has grouped these into two: demand related risks such as seasonal fluctuations, and supply related risks such as disruptions in supply. Moreover, Chopra and Sodhi (2004) have classified supply chain related risks as; delays, inventories, forecasting, systems, intellectual property, and capacity. Furthermore, according to Hallikas *et al.*, (2005) the type of business relationship also has associated risks specific to the industry.

To deal with these issues various risk management models have been developed (Hallikas *et al.*, 2005; Fogg, 2009). Fogg (2009) has defined risk management as "the process of recognizing the risk and minimizing the likelihood of a given risk occurring and the impact to the producing organization if the risk does occur". The process of the risk management includes: identifying risks, assessing the risks, implementing risk management activities, and monitoring. First of all, risks should be identified by taking into consideration different aspects such as late delivery, poor quality. Once that it has been identified then the potential impact of that risk should be assessed. Based on the assessment and remedial action plan should be developed and implemented (Hallikas *et al.*, 2005) Moreover, they have suggested the organization should control itself and try to mitigate the risk by sharing with external suppliers.

Supplier Development

Supplier development activities are typically reactive and meant to solve problems. Fogg (2009) defined supplier development as "provision of finance, technology or other forms of assistance by the buyer to enable the supplier to offer a product or service which meets the buyer needs". Based on Wagner's (2006) research, developing suppliers is a vital part of supplier relationship management, it is a way to improve supplier performance. Purchasing organization need to perform supplier development activities to improve the current situation, realize business goals, and sustain a competitive position in the market (Dyer, 1996). Wagner (2006) and Fogg (2009) have described several motives for supplier development:

- Suppliers performance not being at the desired level
- Lack of capability to meet sourcing requirements
- Need to develop supplier base for better goods and services
- Need to improve supplier and buyer interaction
- Need to pursue new opportunities and ideas
- Realization of sourced products amounting large sum of total costs
- Technology has derived quickly and suppliers should be specializing in particular technologies

Supplier development can be a preemptive approach to solve problems before they even arise (Fogg, 2009), when the suppliers are unable to meet buyer's needs, supplier development can be a proactive approach as well (Handfield, Monczka and Giunipero, 2011). Moreover, organizations should to be concerned about technology sharing, supplier's development initiatives, sharing knowledge, rending resources and with the input of its employees in supplier's processes (Liker and Choi, 2004). Krause and Ellram (1997) has acknowledged the involvement in supplier's operation can be very challenging; therefore, mutual understanding, frequent communication, and strong trust are crucial for successful supplier development.

Various models have been developed for supplier development process, Handfield et al. (2011) and Gocke et al. (2011) have listed the following activities for supplier development:

- Development activities should be targeted on certain number of suppliers
- Establishing cross functional development team
- Focus on what is important
- Engaging and encouraging suppliers
- Identifying opportunities and development possibilities
- Defining metrics and objectives
- Measuring and tracking results
- Establishing feedback system

Therefore, effective supplier development process demands commitment from both suppliers and buyers, in terms of resources and finance, knowledge sharing, and performance measurement (Handfield, Monczka and Giunipero, 2011).

Supplier Relationship Performance Measurement

Measuring the performance of the supplier relationship greatly differs from supplier performance measurement. In contrast to supplier performance measurement, which is done

through defined metrics, supplier relationship performance measurement is more concerned with understanding how both parties involved in the relationship feel about it (Fogg, 2009). Fogg has stated that the performance of a relationship is measured to nourish the relationship with trust, commitment, and devotion.

According to Giannakis (2007) even though, the performance of supplier relationship has not been researched thoroughly, there is a growing understanding regarding its importance due to the increasing level of dependency on suppliers. Performance of a relationship is a complicated and a rather abstract concept which makes it hard to measure (Giannakis, 2007). Where defined objectives are achieved, results could be examined through any performance tool such as balanced scorecard (Cousins, Lawson and Squire, 2008). Conversely, factors associated with relationship such as trust and understanding are difficult to express and quantify (Laeequddin *et al.*, 2010).

Nevertheless, Giannakis (2007) has proposed a method using gap-analysis. Relationship performance is evaluated by measuring the difference between of how both perceive their own and each other's actual performance. The organization's perceptions are derived from how people from both organizations perceive each other's performance. Performance of the relationship is considered high or good if the gaps between two perceptions are smaller.

Leenders et al. (Leenders *et al.*, 2006), on the other hand, has taken a slightly different approach by developing a model this on the level of satisfaction that each party has towards the other. Figure 18 depicts the model.

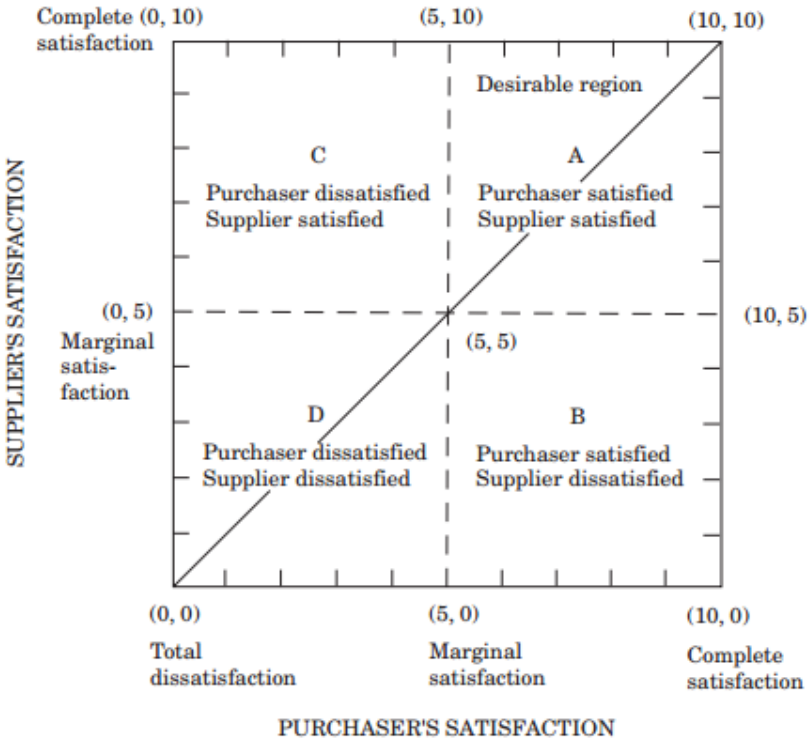

Figure 16 Leenders et al., (2006) buyer-supplier satisfaction model

In the proposed model, buyer's and supplier's satisfaction are plotted on two perpendicular axes ranging from 0 to 10, this results in four cases for relationships. Using this model, each party aspires to achieve the best possible position. By assessing the relationship performance, buying and supplying organization are able to understand each other's perception towards the relationship. It also gives the opportunity for constructive discussions and creates trust (Leenders *et al.*, 2006). Additionally Weele (2014) has identified the benefits of periodically conducting supplier satisfaction surveys to assess supplier's satisfaction and gain feedback for improvement.

4. REQUIREMENTS ENGINEERING

Chapter 4.1 presents the definition of software requirement, 4.2 and 4.2 describe the levels and types of software requirements. In Chapter 4.4 characteristics of software requirements are discussed and Chapter 4.5 requirements development processes is described in detail.

4.1 Software Requirements

The development of a system requires following a systematic approach involving a sequence of steps to achieve a required task, these steps are called software process or life cycle. From an uncertain system functions through implementation and to its practical usage, this process describes the complete life cycle of software products. Various life cycle models for software are discussed in literature such as the waterfall model, transformational model, V model, spiral model, prototyping model (Pressman, 2010). Each of these models starts the software development cycle with requirements engineering Many authors (Kotonya and Sommerville, 2002; Goldsmith, 2004; Pfleeger and Atlee, 2006) emphasize that comprehensive requirements are vital for the development of a high quality system that the users truly need and desire.

"Software requirements" are defined in many ways and there is somewhat lack of common definition in the industry. The IEEE standard software engineer glossary has defined requirement from customer's as well as developer's perspective (Thayer, 2003).

According to IEEE software engineering glossary, "Software requirements are: (1) A state or capability needed to solve a subject problem or achieve a desired objective, (2) a condition or ability that a system or its components must have in order to satisfy specifications, a standard, a contract or any other applicable documents (3) a documented representation of capabilities or conditions described in 1 or 2."

Requirements, in other words, are the features of any system that illustrate the capabilities of that system in order to meet the customer's demands. These are stated in the early phases of the development process in system requirement specification document - a formal declaration of system requirements by the customer, developers and end-users (Beatty, 2013). These requirements explain system's actions and behavior – how system is going to act on the given instructions, objects and transform between different states (Pohl and Rupp, 2011). For example;

- A usage level functionality e.g. the built-in dictionary should offer help when translating from one language to another

- A common system attribute e.g. the system should only allow authorized personnel to log in
- A particular system constraint e.g. data in the working documents should be automatically saved at specific intervals
- A constraint on the system development tools or platforms e.g. system must be built on JAVA platform

4.2 Levels of Requirements

Requirements are broken down to multiple levels of granularity – business requirements, functional requirements, and user requirements – as well as the other non-functional requirements such as maintainability, compatibility, (Goldsmith, 2004). This taxonomy is depicted in Figure 19.

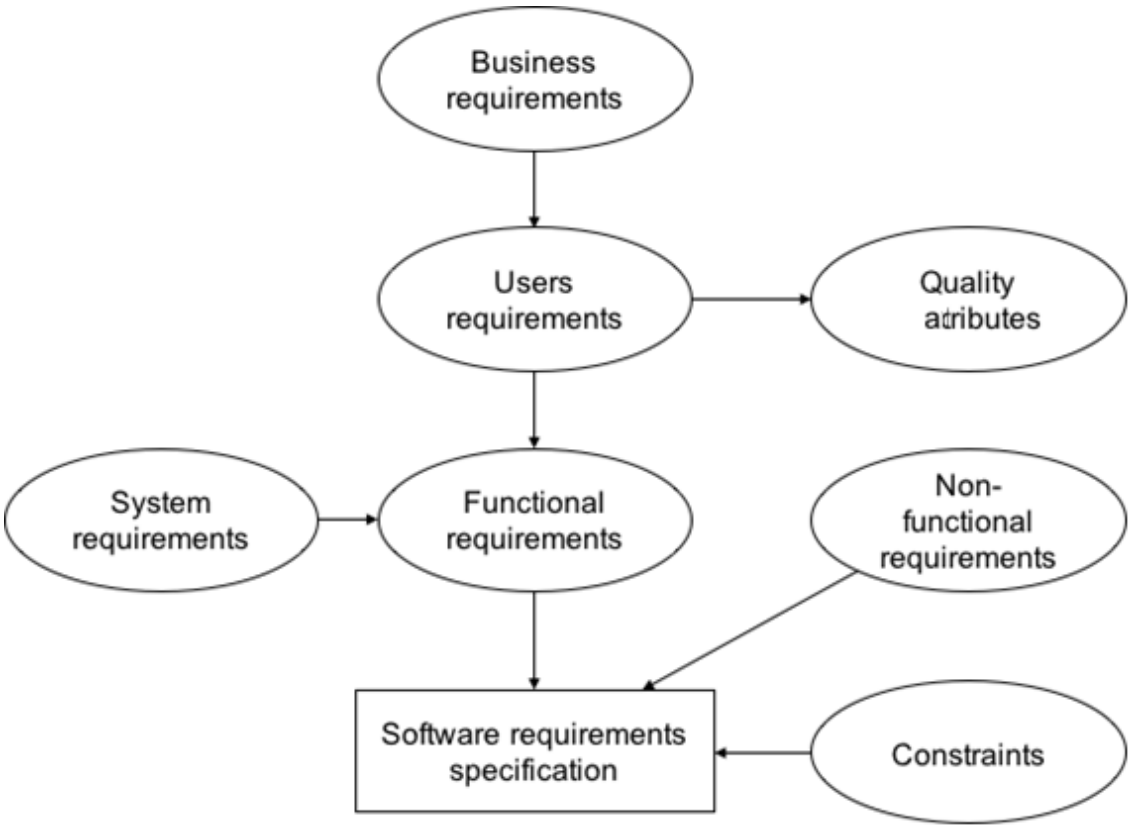

Figure 17 Different components of Software Requirements Specification adopted (Goldsmith, 2004)

Business Requirements
These are the top tier requirements that are required by the system. These are usually derived from the business goals and processes, managers in a company define business requirements for a system that will be used in the company to achieve set goals. All the user requirements must align with the overall business requirements of the organization (Goldsmith, 2004)

User Requirements
These requirements show a collection tasks that users should be able to carry out using the system. Figure above depicts user requirements linked to the quality attributes of the system; these attributes enhance the description of system's functionality by presenting the features of the system in several dimensions that are deemed important to the users and system developers.

Functional Requirements
These requirements explain the interaction between the system and its surrounding environment. They are stated as the inputs and the outputs to the system or between its elements. These are a category of requirements within every tier of requirements (Wiegers, 2003).

Non-functional Requirements
These requirements define the limitations imposed on the system that restrict the options in developing a solution (Pfleeger and Atlee, 2006). These requirements could incorporate any applicable standards, regularity directives and contracts that a system has to conform to; design constraints or quality facets. According to (Pohl and Rupp, 2011), non-functional requirements define constraints on how the functional requirements would be implemented in the system. Constraints confine the choices that are available to the developers in designing and developing of the software products (Goldsmith, 2004).

4.3 Types of Requirements

The definitions presented above do not cover the designing, development, implementation or testing details that explain what type of a system would be built, these make the high-level requirements taxonomy. When exploring these requirement hierarchy in further detail, the types of the requirement can be identified such as for business, user, functional, non-functional requirements. These types need to be taken into account for requirement documentation (Pfleeger and Atlee, 2006). Table 3 describes the types of requirements with examples of corresponding components.

Table 3 Types of requirements.

Types of requirements	*Examples of components*
Physical environment	Where is the equipment to function; Are there more than one location; Are there any environmental restrictions (temperature, humidity)?
Interfaces	Will there be input from one or more other systems; Will there be output to one or more other systems; Is there a prescribed way in which the data must be formatted; Is there a prescribed medium that the data must use?
User and human factor	Who will use the system; Will there be several types of users; What is the skill level of each type of user; What kind of training will be required?
Functionality	What and when will the system do; Are there several models of operations; How and when can the system be changed; Are there constraints on the execution speed, response time?
Documentation	How much documentation is required; Should it be on-line, printed or both; To what audience is each type of documentation addressed?
Data	For both input and output, what should the format of the data be; How often will it be received or sent; How much data will flow through the system; Must any data be retained for any period of time?
Resources	What material, personnel, other resources are required to build, use, and maintain the system; How much physical space will be taken up by the system; Is there a prescribed timetable for system development; Is there a limit on the amount of money to be spent on the development or on hardware and software?
Security	Must access to the system or to information be controlled; How will one user's data be isolated from that of others; Must back-up copies be stored at different locations?
Quality assurance	What are the requirements for reliability, availability, maintainability, security; How must the characteristics of the system be demonstrated to others; Must the system detect and isolate faults; What efficiency measures will apply to resource usage and response time?

4.4 Requirements Characteristics

Requirements explain the information flow as well as the focus on the restrictions imposed on the system functions. In other words, it could be said that requirements play three key roles (Pfleeger and Atlee, 2006), (1) they provide system developers a way to present their understanding of how the user expects the system to work (2) tell developers

the functionalities and characteristics that the resulting product is supposed to have (3) convey to the testing team what to demonstrate to get the customer convinced that the developed system is in fact what the customer had ordered.

Defined requirements must be of high quality, facilitating their thorough use in the development of the system. Therefore, it is necessary to ensure that the stated requirements fulfill the following characteristics:

- Completeness: requirements are complete if all possible states, conditions, changes, constraints are clearly stated in the requirements document. Every requirement must completely state the desired functionality to be delivered, and also must have all the information required to design and implement the functionalities (Goldsmith, 2004).
- Correctness, Accuracy: functionalities should be defined in detail. User and designer, both should accept that requirements as correct and accurate. This means that all the potential errors or misunderstandings have been disclosed (Pfleeger and Atlee, 2006).
- Feasibility: as the requirements are a depiction of users' expectation, it must be confirmed that the system will do exactly that it is supposed to. This means ensuring that the system would be able to meet the requirements.
- Consistency: every requirement must be consistent with the overall business objectives of the final system.
- Verifiable: this refers to ensuring that the system correctly implements the particular functions and all the requirements have been met (Pressman, 2010). Therefore, it is crucial to evaluate every requirement with regards to a testing or verification approach, such as demonstrations or inspections, in order to determine whether the system fulfills the requirements (Goldsmith, 2004).
- Traceability: this refers to the ability to trace a system function or component back to the defined requirements.
- Necessity: each requirement should represent and document a user need or something that is required to meet some external standards or conformity requirements (Goldsmith, 2004).

With terminologies and main requirements characteristics defined, the so-called human factors in the requirements engineering, an equally critical factor in this process will be discussed next.

4.5 Requirements Development

Requirements engineering includes many process that are performed in this framework and the terminologies used are not standard in the literature. In order to avoid confusing relevant vocabulary in this thesis, requirements engineering is divided into sub processes. Figure 20 depicts this division (Wiegers, 2003).

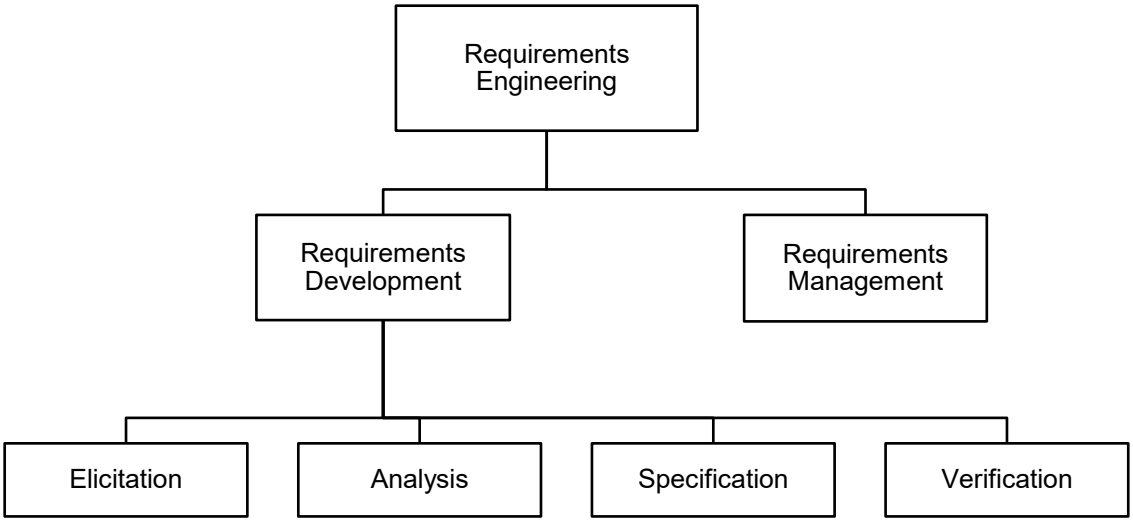

Figure 18 Structure of requirements engineering (adoped Wiegers, 2003).

As shown in the figure, requirements engineering process is divided into requirements development and requirements management. Work done for this thesis mostly focuses on requirements development, and particularly on the requirements elicitations and definition.

4.5.1 Requirements Elicitation

Requirements elicitation is the discovery of requirements for a system through communication with the people who are the stakeholders in the system development. These requirements might not be complete or expressed in a clearly understood manner (Pohl and Rupp, 2011). Developers and engineers work with customer or end-users to determine the requirements, assumptions, hardware and software requirements, and other requirements that are external to the organization. It involves a careful analysis of the organization, business processes, and the application domain where the system will be implemented (Kotonya and Sommerville, 2002).

Effective elicitation of system requirements is crucial; it is not merely the process of transferring knowledge from customer or end users to systems developers and then determine the system specifications. If the requirements are not a true expression of customer needs, project could suffer slippage or, in worst cases, a complete failure. It is hard to achieve good results in this area, since it involves a diverse range of stakeholders who could benefit form system in different ways and might have quite different criterion for

acceptability (Pohl and Rupp, 2011). Requirement elicitation is comprehensive process that involves all the stakeholders. Kotonya and Sommerville (2002) described four dimensions of elicitations process as shown in Figure 21:

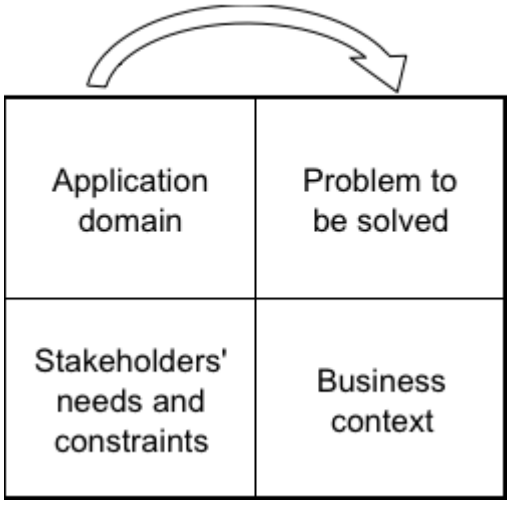

Figure 19 Requirement elicitation components (Kotonya and Sommerville, 2002)

Firstly, the *application domain* focuses on the business domain where the system is going to be implemented; for example, in an accounting support system there must be some background knowledge regarding accounting transactions, bills, and taxes

Secondly, in problem understanding, details of the specific user problems must be understood, here the objective is to extend generic domain knowledge further. Extending the accounting support system example; it has to be clear, for example, what are the taxes involved what kind of invoices company usually receives.

Thirdly, in business context is crucial in recognizing how the implemented system would positively affect the whole business and its branches. For the accounting system example, it must be carefully analyzed that how the billing procedures of the company would be influenced by the new system.

Finally, whilst understanding the needs and constraints of system stakeholders, it must be recognized that they are the people for whom this system is intended. Therefore, here it is a crucial to further drill down into specific details to determine the needs of the customer. There should be a clear understanding of the procedures that this system would needed to support (Kotonya and Sommerville, 2002).

Requirements elicitation is a collaborative process between system developers and stakeholders that comprises of all the above-mentioned processes. In an effort to mine all the

relevant information, developers utilize different tools and techniques (Kotonya and Sommerville, 2002). Three of the common techniques are explained below:

- Conducting interviews is a very common method, these can be very effective to understand the problems and to extract the general system requirements. However, these are not as effective in the analysis of application domain and the organizational issues affecting these requirements. There are two types of interviews (Kotonya and Sommerville, 2002); (1) closed interviews here the requirements are gathered using a predefined set of queries, (2) open interviews, these do not have a predefined agenda that guides the whole conversation with stakeholders. In practice, the difference between these two types of interviews is somewhat minimal (Kotonya and Sommerville, 2002).
- Scenarios. During the requirements gathering process it is quite handy to construct a collection of interaction scenarios to clarify the requirements. Scenarios could be example situations of where interaction between the end user and system takes please (Pohl and Rupp, 2011). End-users' interaction with the system is simulated using the scenario; basically, common system users describe what do they want achieve and what information do they need from the system in order to perform the task in the scenario (Kotonya and Sommerville, 2002). Although creating scenarios is a time-consuming task but this elicitation method does result in a better gathering of requirements.
- Prototyping, it is a compilation of initial system version available at early stages of the development cycle (Kotonya and Sommerville, 2002). Meaning, all functionalities might not be included, typical management can be ignored, non-functional requirements are not closely followed, etc. there are a number of methods to develop prototypes such as; (1) throw-away prototypes, these are developed to gather system requirements that are the most difficult to understand. (2) evolutionary prototypes, this kind of prototypes are made to quickly develop a system that is workable with only well-established requirements that the system is going to support. The biggest benefit of using prototypes to elicit the requirement is and that it enables customer to visualize, play around with the requirements and features to reach the most suitable solution. (Kotonya and Sommerville, 2002).

4.5.2 Requirements Analysis and Negotiation

This section describes the relationship of the requirements elicitation process with requirements analysis and negotiation processes, Figure 22 depicts this relationship. The aim of requirements analysis and negotiation is to form a set of requirements there are complete, consistent, and true expression of customer needs. Requirements analysis process helps discover missing requirements, vague requirement, conflicting requirements,

and overlapping requirements. (Pressman, 2010) When overlaps or conflicts among the requirements are discovered, these requirements are then modified through negotiation with the stakeholders.

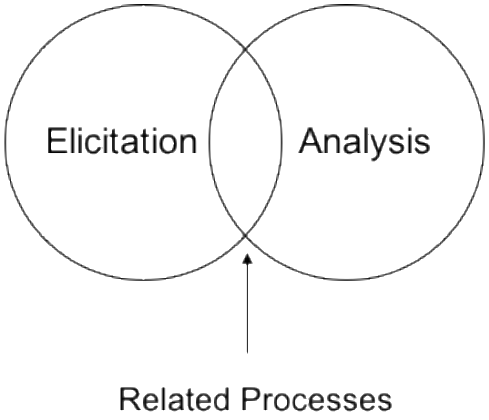

Figure 20 Interaction of requirements elicitation and analysis.

Essentially, through analysis and negotiation process, aim is to establish a set of requirements that satisfy the needs of all the stakeholders. Sometimes analysis is interlinked to requirements gathering process, in those cases problems with the requirements become evident already when the requirements are stated (Kotonya and Sommerville, 2002). Nevertheless, usually a further analysis of the requirement is performed after the initial draft has been prepared.

4.5.3 Elicitation and Analysis Process

As shown in the Figure 23, requirements analysis and elicitation are connected to each other, sometimes analysis is already performed as the requirements are being gathered, and this in turn helps identify current problems. Therefore, these processes can again be considered as a spiral development model (Kotonya and Sommerville, 2002), as it is depicted in Figure 20.

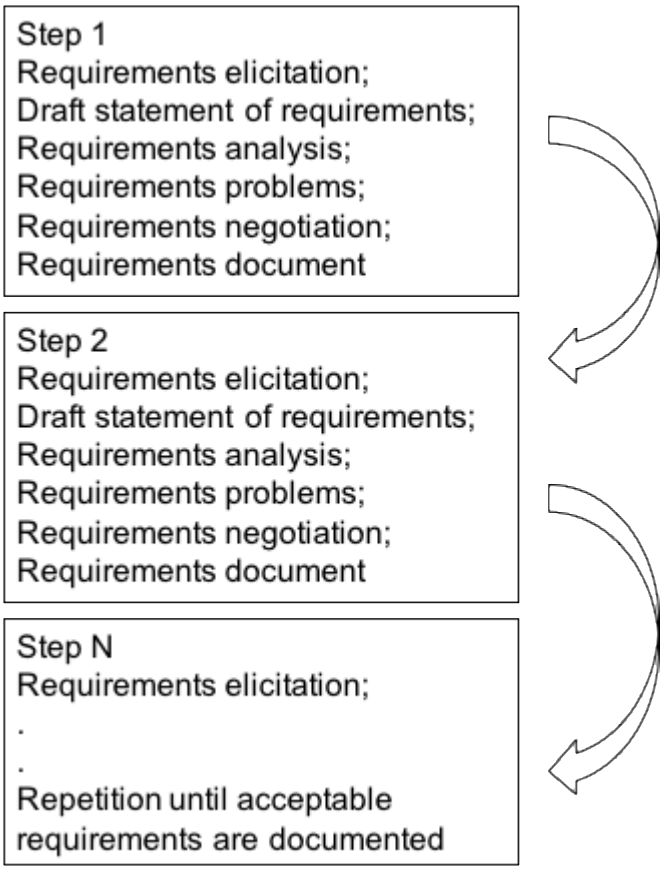

Figure 21 Requirements engineering spiral model (Kotonya and Sommerville, 2002)

Requirements engineering team gets this information from the stakeholders, this information is analyzed to weed out unnecessary requirements and to verify consistency, feasibility, correctness and completeness of the requirements. After identifying these, engineering team proposes changes or improvements to the requirements and negotiates with the customer, and another spiral round is followed (Pohl and Rupp, 2011). This process continues until all the stakeholders are satisfied.

5. CONCEPTUAL FRAMEWORK

Chapter 2 discussed in detail the engineering procurement and construction (EPC) projects, and the supply chain for construction industry. The diferencs between supply chains in construction industry and manufacturing industry were identified through an extensive study of existing academic literature. In Cahpter 3, the concepts of supplier relationship management was introduced, different type of supplier relationships, and the benefits of supplier relationship management were described. In the end, different supplier relationship management activities were discussed. Chapter 4 discussed the requirements engineering concepts, types of requirements, level of requirements, and requirements gathering and analysis processes were discussed. The conceptual framework for this thesis Sean in Figure 24 below:

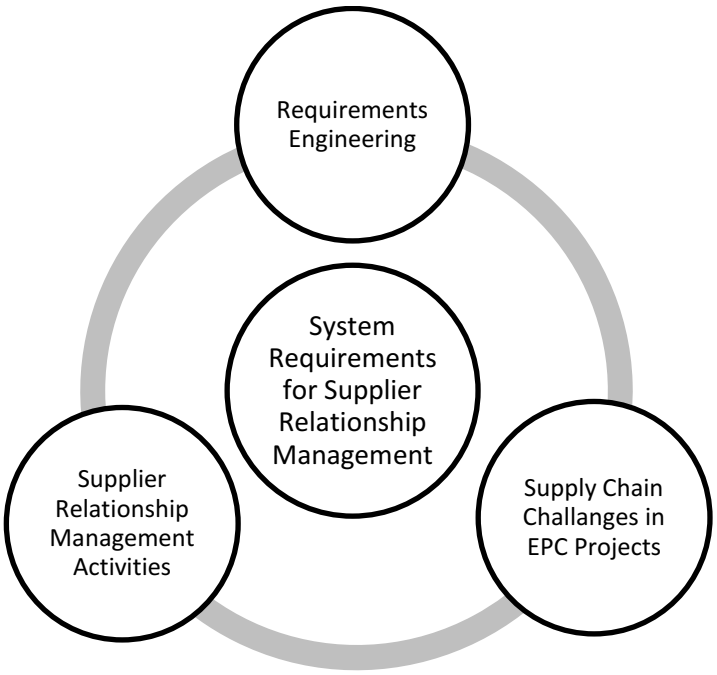

Figure 22 Conceptual framework.

As, the purpose of this thesis is to define the requirements for supplier relationship management system suitable for an EPC contact firm. Once the key areas for interacting with the suppliers have been identified, key activities and areas of potential improvements for managing supplier relationships would be established. Based on this information and through requirements engineering techniques, the software needs and the requirements for a supplier relationship management system for the case company would be specified.

6. CURRENT STATE PROJECTS

In the EPCM projects delivered by the case company clients have a varied degree of involvement in the procurement phase, which defines the company's interaction with the suppliers in the project. Companies interaction with the suppliers and procurement activities in the projects can be divided into two types; procurement where clients do operative purchasing, and procurement on behalf of clients. These two are described in more detail here.

6.1 Projects Operating Purchasing by Client

In this type of projects, operative purchasing is done by end clients. Project needs are defined by the EPCM contractor, purchase requisition is prepared and sent to the client's procurement. Client procurement personnel gather bids from the already approved supplier base, commercial evaluation is done by the client the procurement personnel and the technical evaluation is performed by the EPCM contractor's engineering department. Depending on the nature of the purchase, client negotiates the contracts with the suppliers, EPCM contractor's technical expertise is used in the negotiation process when needed. Once the contract has been signed, it is transferred to the procurement organization of the EPCM contractor this process is depicted in Figure 25 below:

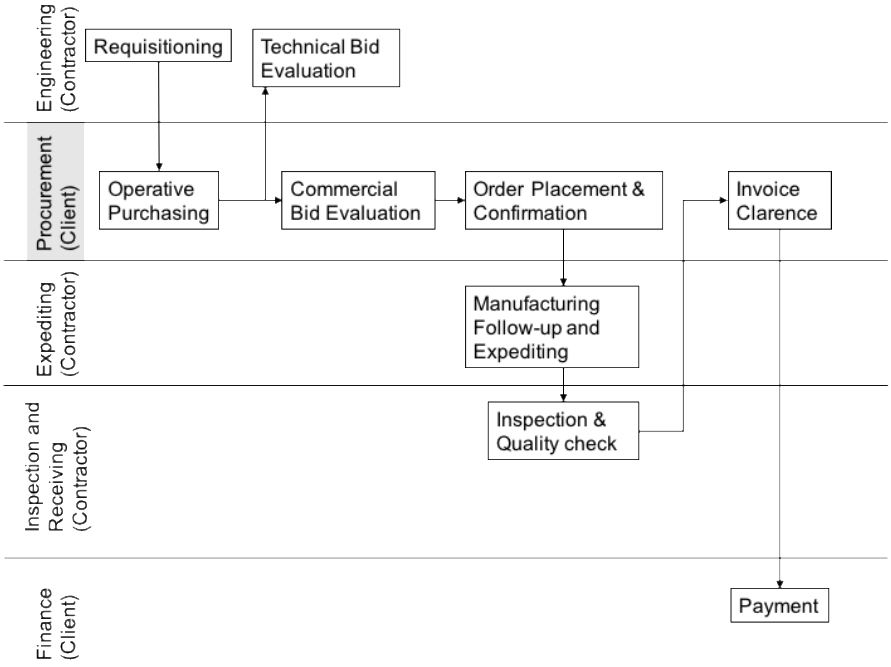

Figure 23 Projects Operating Purchasing by Client

Procurement personnel of the EPCM contractor do all the necessary expediting of purchased equipment and materials. This includes progress follow-ups, inspection and testing activities in the supplier's facilities during the manufacturing of the products. Upon completion of the delivery, purchased equipment and materials are received by the client's or contractor's warehouse, larger equipment is directly sent to the project construction site. Final or intermediate invoices are sent by the suppliers directly to the clients, who upon confirmation make the payment.

In projects of this kind, EPCM contractor's role becomes relatively limited when it comes to supplier relationship management. In this case, clients usually have their own supplier management processes. Clients provide EPCM contractor the approved suppliers list for different categories. Clients qualify these suppliers for the projects after ensuring that the suppliers meet their defined requirements, maintaining the supplier base and managing relationships with suppliers is client's responsibility. In these projects client bares all the financial responsibilities for the purchasing activities.

6.2 Procurement on Client's Behalf

In these type of projects, operative purchasing is done by EPCM contractor's procurement personnel. Project needs are defined by the EPCM contractor, purchase requisition is prepared by the engineering and sent to the procurement organization. Contactor's procurement personnel gather bids from the approved supplier base, commercial evaluation is done by the procurement personnel and the technical evaluation is performed by the engineering department. Depending on the value of the contract, EPCM contactor is authorized to negotiate the contracts with the suppliers on behalf of the client. However, if value of the contract exceeds a defined limit then clients are also involved in the negotiation process. This process is depicted in Figure 26.

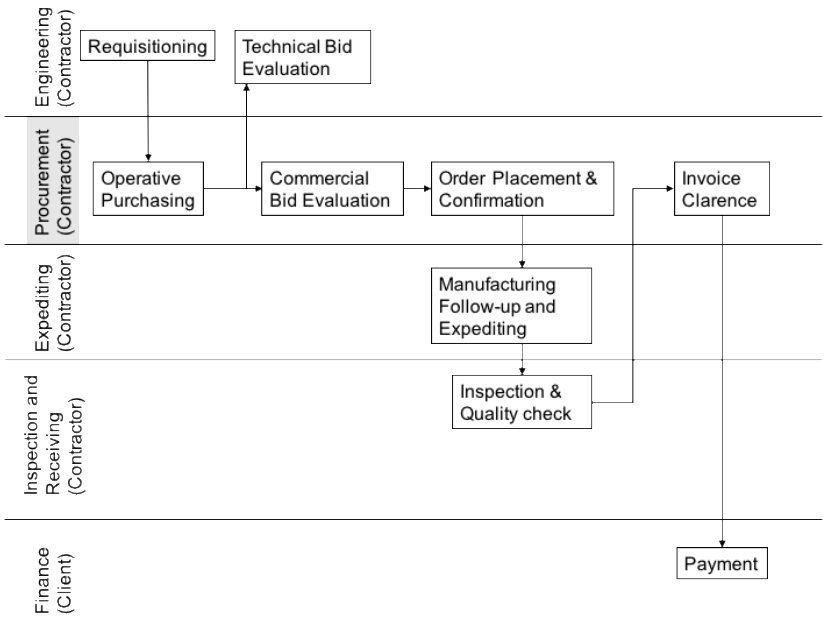

Figure 24 Procurement on client's behalf.

Once the purchase orders have been placed, EPCM contractor takes care of the expediting and subsequent inspection and testing activity during the production. Upon completion of the contract, client is invoiced directly by the supplier. A key difference between these projects and the ones explained in the previous subsection is that the EPCM contractor is responsible for operative purchasing. In this kind of projects, EPCM contractor is bit more involved in the procurement activities of the projects. Supplier selection is performed by the clients with the help of EPCM contractors. However, only client's financial resources are used for all the procurement activities. The requirements defined in this thesis are more focused on where contractor does the operative purchasing.

7. BUSINESS REQUIREMENTS ELICITATION

The data collected in the qualitative interviews pointed towards many different aspects in the complete supplier relationship management process that required attention. After an analysis of the interviews, the responses related to similar matters can be grouped together to develop and understand the relationship between them. The following section presents the analysis of their responses.

7.1 Supplier Registration and Qualifications

Currently, the case company utilizes the product from the suppliers that are already approved and qualified by the clients, this information is provided in the form of lists to the case company. These lists are provided and maintained by the clients themselves. In addition to those, case company also has information about potential suppliers on its own. However, this information not systematically collected and maintained. As one of the participants expressed *"…for us to be able to deliver Turnkey solutions, we should have our own supplier database via information regarding the existing suppliers is it regularly updated and potential new suppliers are included".* When asked about how new suppliers currently establish their contacts with the company, many responses highlighted the need for a systematic approach for managing these contacts. As a one of the respondent from purchasing described the situation, *"…we usually get information about the new suppliers and their products through emails… or when sales personnel at the new or existing suppliers send a marketing material to us".* In addition to that, engineering disciplines seldom invite suppliers and provide them a chance to promote their products. Another uncommon way to discover new suppliers is through visiting exhibitions.

Since illegal requirements in the process industry plants are quite strict, therefore, statutory compliance for the products and manufacturers has to be carefully assessed. This requires thorough information collection about the potential suppliers and their offerings. Depending on the application, different products need to meet different criteria. As one respondent explained *"…equipment and materials used in the process industry need to comply with different standard, therefore, different information is required from the supplier".* In some cases, supplier information has to be validated as well, as one of the respondents explained *"… for complex deliveries (as a buyer) we need to make sure that the supplier is capable of delivering the required equipment. This requires visiting supplier's facilities for audits*". Additionally, financial situation of the suppliers is also assessed in many places. Once all this information has been collected and verified, only then a supplier could be qualified as approved or not approved. A schematic diagram of this whole process is shown in Figure 27 below:

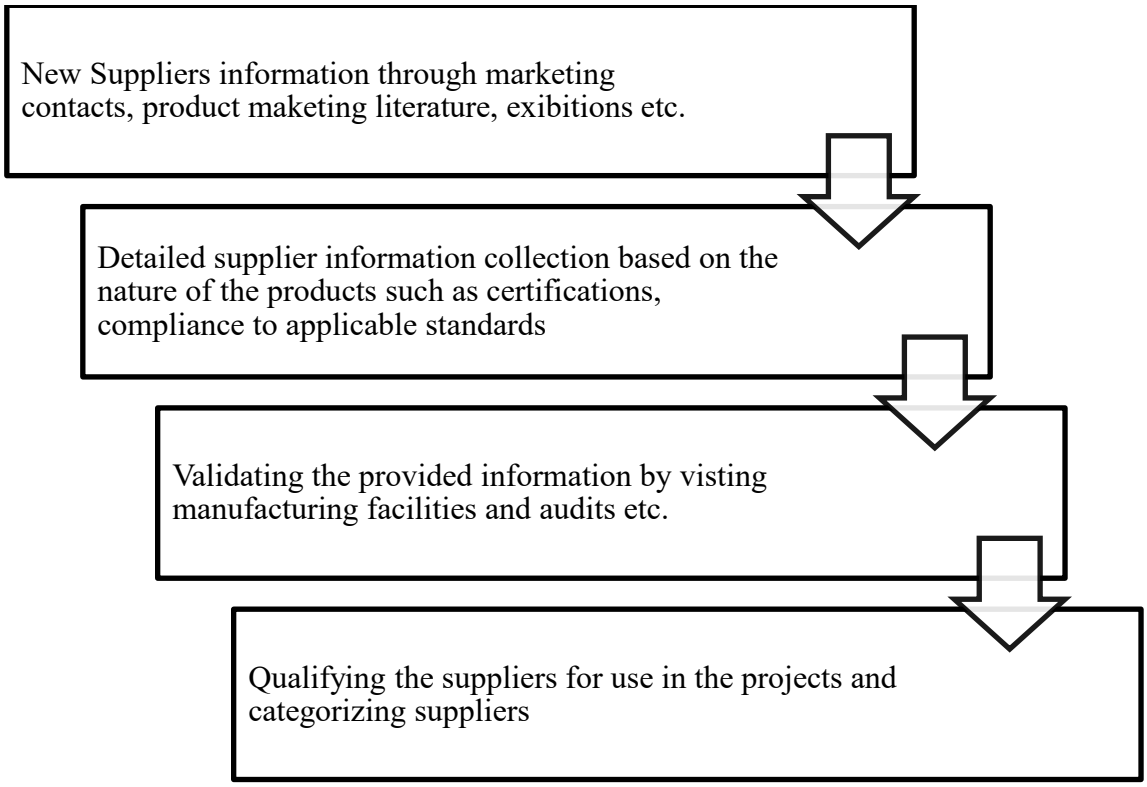

Figure 25 Registration and Qualifications of Suppliers.

Identified System requirements:

From the above discussion, the need to develop a database is quite evident where supplier information could be collected and maintained. From the discussion presented above and from the responses in the interviews, following requirements for a system are identified to effectively manage supplier registration and qualification:

Table 4 Identified Requirements for Supplier Registration and Qualifications

Requirement	**Description**
Digital supplier database	Functionality to create and maintain a digital supplier database
Supplier registration	Registration of suppliers in the database as the first step
Supplier categorization	Ability to categorize suppliers based on the predefined criteria

Supplier information collection	Collecting the required supplier information according to respective categories
Validate supplier information	Validating the supplier information submitted into the system
Supplier qualification & Approval	Assessing the supplier qualification and creating approved suppliers base

Currently, several functions of the company; electrical, instrumentation, mechanical, automation, equipment and materials purchasing, and services purchasing, have a somewhat separate body of information relating to suppliers. This information is available in spreadsheets, electronics sales portals, and the magazines. Developing a centralized supplier database could help collect and maintain this information more effectively. A supplier registration process in system to develop supplier contact, instead of using emails. Upon registration, suppliers could be categorized according to a suitable criterion for specifying the necessary information required regarding products and suppliers. After collecting the information in the system, the necessary steps would be followed such as cross-checking or audits already validate the information. Once all the required information has been collected in verified, suppliers will be qualified according to the predefined criteria and database of approved suppliers could be developed.

7.2 Product Catalogue

Currently design engineers working in different disciplines consultant multiple sources of information when defining requirements or preparing purchase requisitions. As one of the participant described *"...we collect product related information from several sources... product brochures, datasheets and other marketing material. Most of this information is stored in the portal accessible to the designers".* The portal is maintained and updated by internal personnel. In case, the latest information is not available in the portal, participant continued, *"...we also use manufacturer's websites and other internet sources like online technical forums or communities".*

Regarding the usability of the portal and other sources, one of the participant told *"...we have the information available in the portal and other systems... you can find what you're looking for, however, it could be really time-consuming sometimes. Especially, if you are not certain where the information might be".* This search functionality available in the portal it also not very effective. Regarding the availability of product information in a potentially new system one of the participants suggested *"...the manufacturer's websites*

usually have the latest information available regarding product, having the (external website) links in the product database could be quite useful".

Identified System requirements:

Not all the departments of the case company seem to feel a very strong need for having product catalogues. However, some departments, especially those involved in working with a variety of equipment regularly, feel the need and value of having such a system. Some of the identified requirements from interview data are presented below:

Table 5 Identified Requirements for Product Catalogue

Requirement	Description
Digital Catalogue	Ability to set-up centralized digital product catalogue
Search functionality	Ease of use and ability to search based on categories, product information etc.
External hyperlinks	Ability to add external hyperlinks for products to manufacturer's website
Product documentation	Ability to store product related documentation

A centralized product catalogue could eliminate the need to consultant multiple sources and manage product related information for different departments in a more effective manner. Having the ability to search for product with different search criteria would reduce the time to find relevant products and information. Availability of external links from the manufacturers' website insures the availability of latest information.

7.3 Supplier Performance Management

One of the recurrent themes in the interview responses is the challenges related to supplier performance management. This appears to be very complicated due to the fact that a variety of goods to services are sourced for any project, from proprietary high-tech equipment to bulk materials, and from construction services to engineering subcontractors. Functional categorization of these is shown in Figure 28.

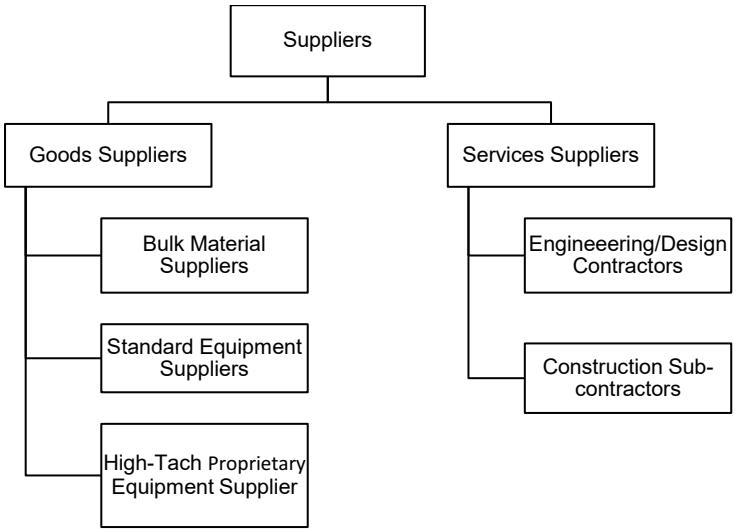

Figure 26 Types of Suppliers

- **Bulk Material Suppliers**
  Bulk materials are most times the cheapest in terms of unit price; these include pipes, fittings, cables, nuts, bolts, and other similar products. Suppliers and buyers usually have frame agreements in place for this type of material. Performance of the supplier is primarily related to the performance of the delivery, and for any project, the purchase orders for bulk material can be quite huge with a large variation in value. As one of the participants explained, *"We have a large number of orders worth from a few hundred euros or less to hundreds and thousands of euros. So, evaluating each and every delivery is not feasible".* To address this issue all the deliveries higher than a certain value are supposed to be evaluated, however, this in turn creates further complications. The respondent continued, *"... this is a double-edge sword… if deliveries up-to a certain (monitory) value are evaluated, it is possible that the smaller orders might add up to a more significant amount".* In addition to these, quality of the products is also needed to be considered.

- **Standard equipment suppliers**
  These kinds of equipment are more and less standard off-the-shelf items that do not require any project specific designing. These products include sensors, electrical motors, and valves among others. Evaluation of the deliveries is a relatively simple, as one of the participant explained "…for most projects, the number of such deliveries is not significantly huge. And the (monitory) value of these deliveries is also not very small in most cases". Therefore, certain quantifiable parameters could be used to evaluate the delivery. As one participates described *"... in these cases, evaluating the delivery accuracy, compliance to the schedule, lead*

time, price, documentation and quality can give a reasonable measure of performance". Most of the parameters suggested by the participants can be recorded and evaluated in the system to assess the performance of the supplier.

- **Proprietary equipment suppliers**
  These are complex packaged deliveries that require extensive engineering and are designed according to the specifications for each project. Every project includes only a few of such deliveries; however, these are extremely critical because most of the other activities depend on these. These are long lead-time items and require extensive collaboration between the supplier and EPC contractor. Therefore, evaluating supplier performance gets even more complicated. As one of the participants described *"…our engineering depends on these deliveries to progress …getting the information (equipment specification and engineering designs) from these suppliers in a timely manner is extremely important".* Another important aspect the quality of the information provided by these suppliers, according to one participant *"…sometimes it can take multiple revisions (of engineering drawings and other documents) and commenting cycles to reach the correct one".* A more soft-aspect here is the manner of collaboration by the supplier, as these kinds of deliveries can take multiple years sometime. Throughout this time, there are recurrent meetings and visits to manufacturing facilities for inspection and testing purposes, evaluating these is important. Naturally, contractual compliance is crucial, still, evaluating these kinds of suppliers requires a more thorough and comprehensive approach.

- **Engineering Services Providers**
  Engineering services include specialized design work such piping layout design, process designing, materials specialists, consulting services for specialized processing technologies. Suppliers of these services could be located virtually anywhere. The suppliers could be contracted for specific project needs or certain design work could be outsourced to them entirely. Therefore, assessing the performance requires careful analysis, as one of the participants explained, *"…we may have one contractor working on one part of the piping layout and another contractor working on a different part and the problems may arise in integration".* Additionally, there are dependency issues *"...an engineering company does the design work and a construction company doing the installation…. if something goes wrong then it becomes challenging… was there something wrong in the design or the installations are based on those design were not done correctly".*

- **Construction subcontractors**
  EPC contractors use a host of subcontractors in the construction such as mechanical installations, electrical work, welding, and civil work. To ensure the safety and quality standards of the case company and its clients, compliance to HSEQ

(health, safety, environment, quality) guidelines of the company are very closely monitored for every subcontractor at construction site. These factors are evaluated for every subcontractor before the project, regularly during the project, and after the project as well. There are Excel templets, evaluation reports, and questioners for subcontractor and for the company. All this information is stored in the company's database.

Because of the different natures of products and services, a comprehensive and systematic approach is required for the supplier performance evaluation. Categorization of suppliers is needed to evaluate the performance against set criteria. These measurement results should be shared with the suppliers so that the appropriate remedial plans could be developed and followed up. Schematic overview of this process is shown in Figure 29

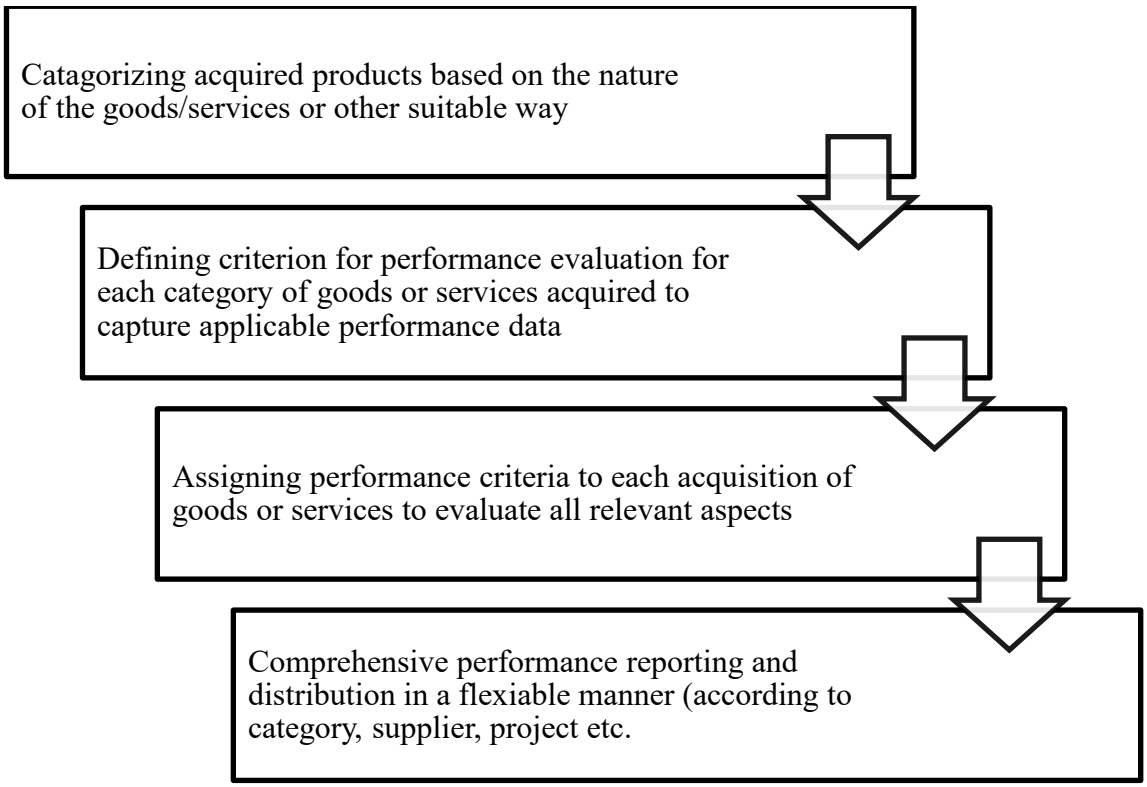

Figure 27 Supplier performance management activities.

Identified System requirements:

As explained above, there are a number of challenges in supplier performance evaluation and management. Without taking into consideration the most of, if not all, the deliveries it is difficult to get a true picture of the supplier performance that can be really time and resource consuming. Company's attention and approach to performance evaluation are

quite clear, as one of the participants described *"...evaluating the performance of deliveries should be designed into the way of working".* Therefore, the more system can you picture to report performance the better it would be. Some of the identified requirements for performance management are listed in the table below:

Table 6 Identified Requirements for Supplier Performance Management

Requirement	**Description**
Supplier/ product segmentation	Ability to categorize suppliers or products to assign the most suitable of performance evaluation criteria
Defining evaluation criteria	Ability to configure evaluation criteria (KPIs, scorecards), so that all the relevant information is collected.
Performance reporting	Comprehensive performance evaluation and reporting in as least resource intensive way as possible
Development plans and follow-up	Ability to create and share development plans and follow up on the needed actions

7.4 Operational Procurement

Operational procurement refers to the purchasing process, sometimes also referred to as the Procure-to-Pay (P2P) process. It includes the order process, supply process and payment process. Case company has a well-defined procure-to-pay including all the roles and responsibilities. Due to the confidentiality requirements, the actual process cannot be shared here, a simplified description of the processes presented here. Once the project need have been defined, design engineer is preparing those regulations. A purchase requisition is a request for ordering goods or services that states the need such as quantities, technical requirements, applicable standards related requirements, and delivery time.

Once the purchase requisition has been created, it has to be approved by the concerned responsible which could be next level managers or a subject matter expert. Ordering or sourcing process starts after the approval of the purchase requisition, it includes sending out enquiries to suppliers, receiving and evaluating quotations, negotiating with the suppliers and order replacement. Depending on the purchase, there could be multiple negotiation rounds and sign-off authorities before the order is placed. All the goods inspected after receiving and the invoicing process starts. It includes receiving invoice, registering and checking against received goods, and paying the invoice. The whole process is depicted in Figure 30.

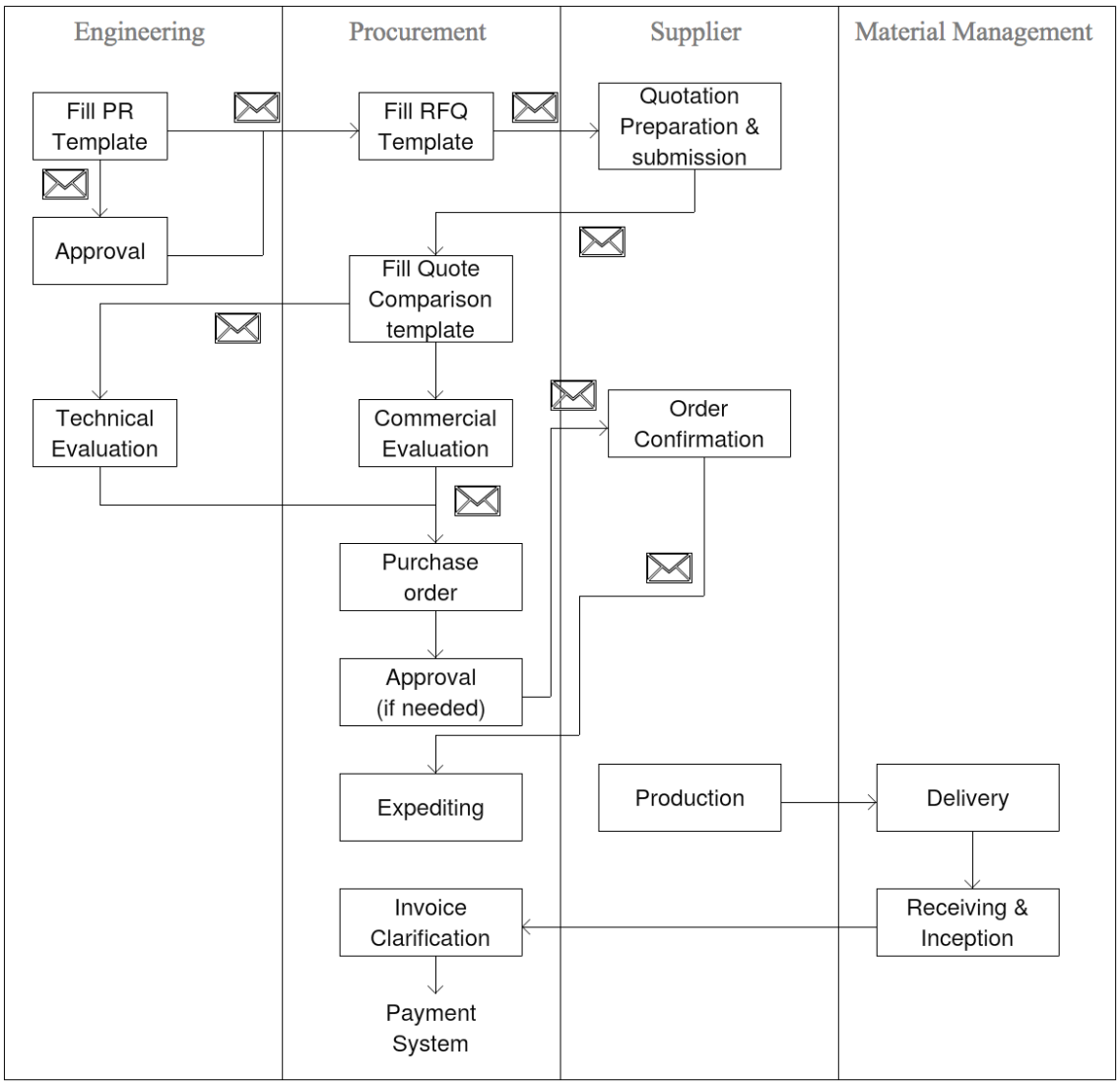

Figure 28 Operation Procurement Process

All of these activities utilize spreadsheet and word processor templates while creating, and are transmitted through emails. It is not only less time-consuming and resource intensive process but also can cause delays. Regarding such transmissions, one of the participants expressed *"…as long as some document is in someone's inbox… it is already a bottleneck".* One of the company's strategic goals is to have more digitalized processes and ridding of manual works much as possible.

Identified the system requirements

From the above discussion, interview responses, and company's processes, a number of system requirements are identified. These requirements are presented in Table 7.

Table 7 Identified Requirements for Operational Procurement

System Requirement	Description
Requisition creation & approval	Creating, approving, and issuing purchase requisition in the system
Electronic RFx documents	Ability to create and send out electronic RFx (request for information/quotation/bids) documents in the system
Collecting responses	Ability to collect the quotations/bids from this supplier in the system
Bids evaluation	Ability to reform technical and commercial evaluation of the bids collected in the system
Order placement & sign-offs	Signing-off the purchase orders and sending out orders to the suppliers. And receiving confirmations
Receiving and invoicing	Ability to receive the invoice, comparing against the received goods, and approving invoices for the payment

Equipping operational procurement digitalized processes would eliminate the cumbersome tasks of using spreadsheet/word processor templates, reduce the time consumed and remove bottlenecks. This would also allow better control by ensuring the visibility of the whole purchasing process all the way from requisition to final invoice payment.

7.5 Miscellaneous Requirements

Some of the requirements that could not be included in the above groups are presented here in Table 8.

Table 8 Miscellaneous Requirements

System Requirement	Description
Supplier data maintenance	Collecting, storing, and maintaining supplier credentials documents. Flagging Active obsolete duplicate suppliers in the system
Notifications	Ability to log activities related to a delivery or a supplier
Activity logging	Alerting concerned user when an action is required

Supplier portal	Is self-service supplier portal to manage supplier data, submit response to electronic RFx

Managing supplier's credential documentation such as certifications, quality standards, financial reports, audit reports, in the system would make the management and use of such documents more efficient. Four examples, alerting these users my email then a certain certificate has expired and is no longer applicable, and then update is required. One of the useful functionalities would be to register activities such as meetings, inspections, and teleconference, within the system related to specific delivery are a supplier. This would help in keeping track of the deliveries, particularly long lead-time items, and by giving more accurate resource utilization for cost control.

Since collecting, storing, and maintaining all the supplier data internally can be resource intensive. As one of the senior managers expressed *"... our first priority is to have the resources available for the project as much as possible. So, the more we can automate these processes the better it is".* Therefore, a self-service portal for the suppliers would be a huge time-saving feature. It will also enable maintaining the supplier letter more efficiently since all the suppliers what has the ability to update their necessary data when it is required.

8. USER REQUIREMENTS AND USE CASES

This section describes the user requirements for supplier relationship management system. Similarly, as in the previous section, the requirements are grouped together for four processes. A possible flow of activities is also presented, use case diagrams are used to illustrate these functional requirements.

8.1 Product Catalogue

One of the main problems identified from the responses by the engineering departments is the lack of a system where products related information could be gathered from different sources. Currently, this information is dispersed and in different formats, one of the information sources is an engineer's portal for each discipline. This portal is maintained internally, sometimes the information is outdated which requires consulting other sources. The search functionality available in the portal is also not as effective as desired. Figure 31 shows the functional requirements related to product catalogue.

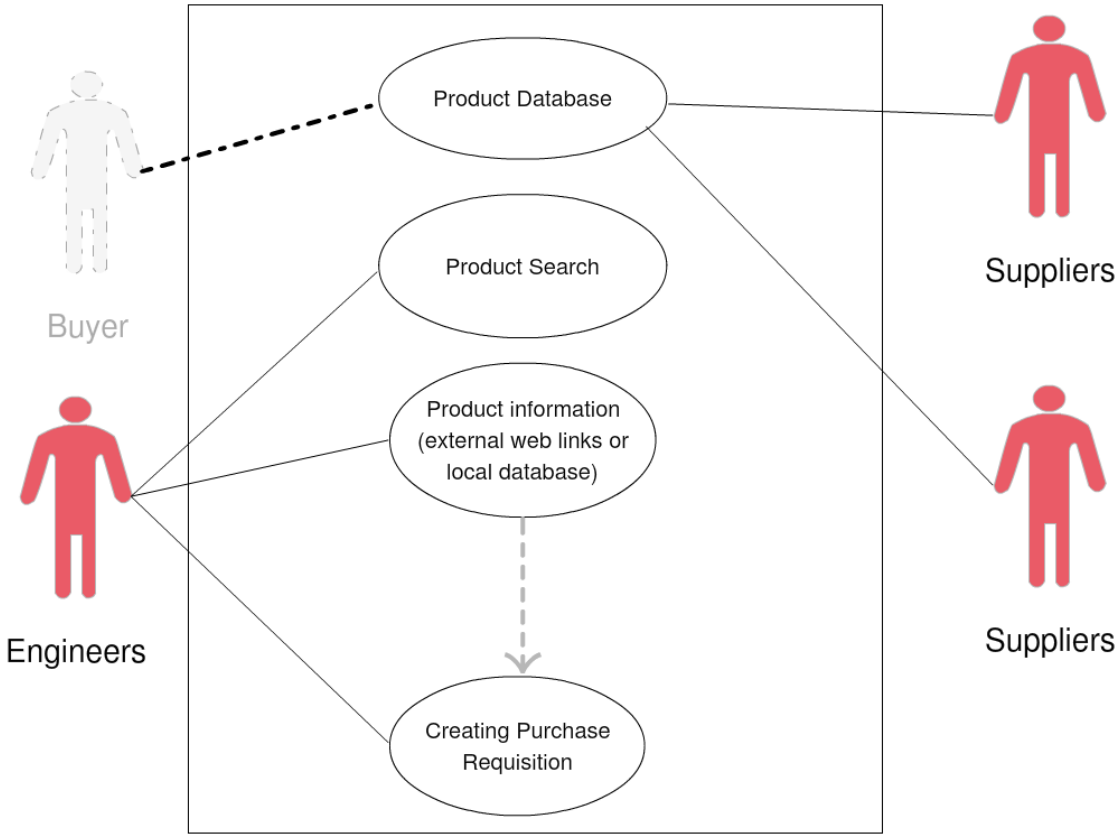

Figure 29 Use Case: Product Catalogue

The system should offer functionality to develop and maintain a unified product database where product information could be collected and maintained in a uniform format. The

buyers and suppliers should be able to update the database with new products or up-to-date information related to existing products. Suppliers would keep the information updated with buyer primarily validating and overseeing the changes made to the database. The system should offer an efficient search functionality to find the products and related information quickly. Since, manufacture's websites usually have up to date information on products, hyperlinks to the product webpage on the manufacturer's website would enable to access latest information automatically. This could also reduce the need to constantly update the information stored in the system's local database. The system should also offer the functionality to utilize the product information when creating purchase requisitions in the system

8.2 Requisition and Purchasing

Once the purchasing needs have been identified, a Purchase requisition has to be repaired. As explained in the requirements related to products catalogue, user would search and select the products from the catalogue. The system should offer the functionality to create purchase requisition in the system and specify products in the requisition directly from the catalogue. The requisition should be approved in the system and forwarded for procurement. Based on the received purchase requisition, purchaser should be able to generate electronic request for quotation/ bids. Purchaser should be able search and select suppliers and send eRFX to potential suppliers. The system should offer and the functionality to perform these activities within the system, eliminating they need to use spreadsheet or word processor templates and send those through emails.

Selected suppliers should be able to submit the bids directly to the system for competitive bid evaluations. The system should offer the functionality to perform technical evaluation by the engineers and the commercial evaluation by the procurement personnel in the system. Once a bid has been selected, a purchase order would be generated. Since, these are cases where purchase orders have to be approved and signed-off by multiple times. The system should offer the functionality to define approval and sign-off hierarchies for purchase orders. The purchase order would then be sent to the selected supplier.

The supplier should be able to confirm the orders in the system and submit relevant information for purchaser. Once order is confirmed by the supplier, expediting activities for manufacturing and production would follow. Performance of the complete delivery would be evaluated and saved in to the supplier profile. Figure 32 illustrates the functional requirements related to requisitioning and producing.

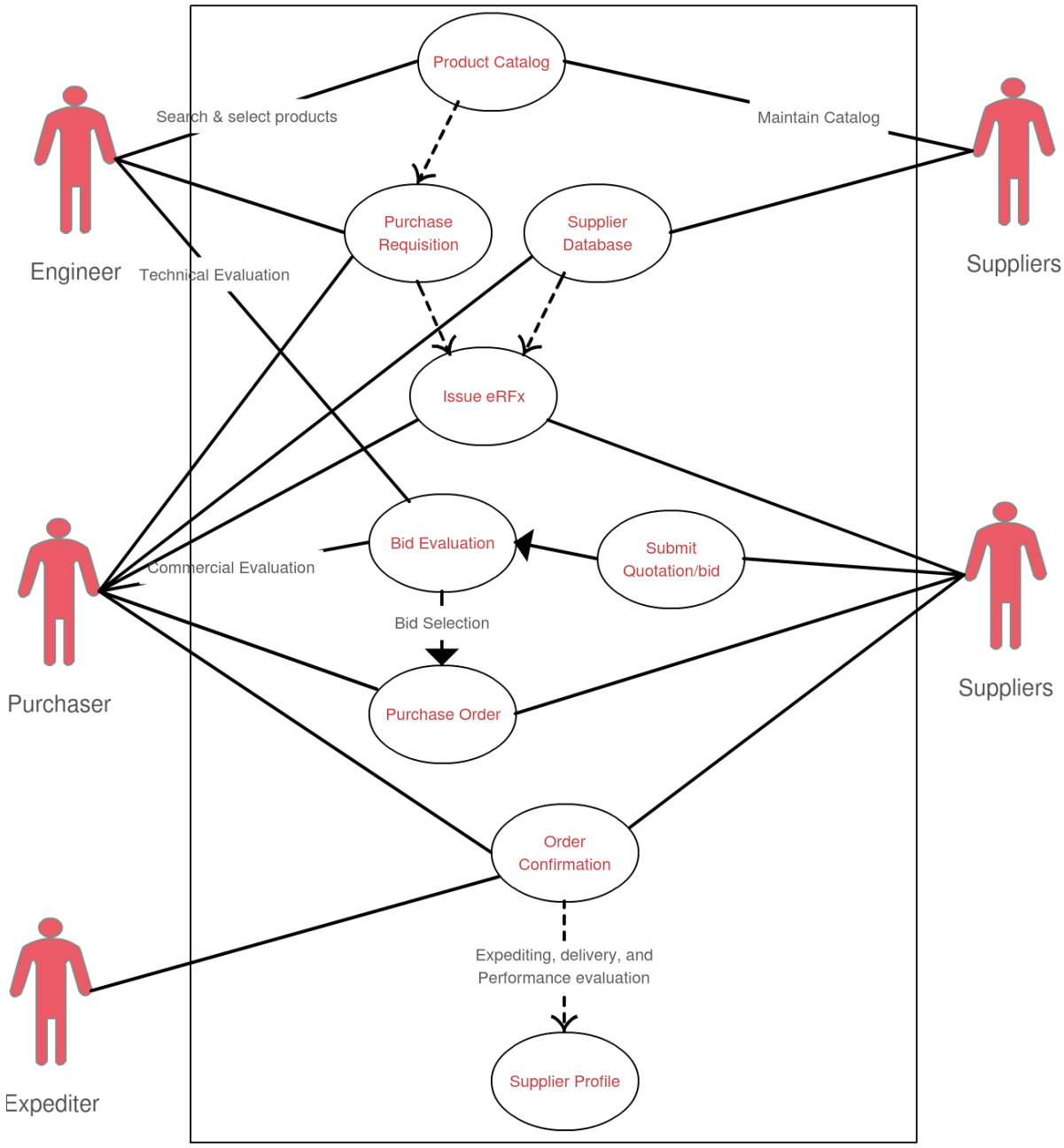

Figure 30 Use Case: Requisition and Purchasing

Automating this whole process would make the whole process more efficient by eliminating the use of templets and sending emails. This will also help in performance management by increasing the visibility off the whole of process. Performance management factuality requirements are explained in the detail in the next subsection.

8.3 Performance Management

As explained earlier, the nature of products and services acquired for projects is quite diverse. This requires different aspects to be considered for performance evaluation, to address this issue different evaluation criterion needs to be developed. The system should offer the functionality to develop different evaluation criterion according to the nature of the product or service acquired with roles and responsibilities. Once a purchase order for goods or services is generated, system should offer the functionality to assign the applicable evaluation criteria to the purchase order.

System should have the functionality to gather feedback from relevant stakeholders, for instance complex equipment delivers involve different engineering disciplines. Therefore, feedback collection and performance evaluation from different perspectives is quite important. The system should offer the ability to collect and process this feedback in a way that would be comprehensive and easy to comprehend. Figure 33 below depicts the use cases for performance management.

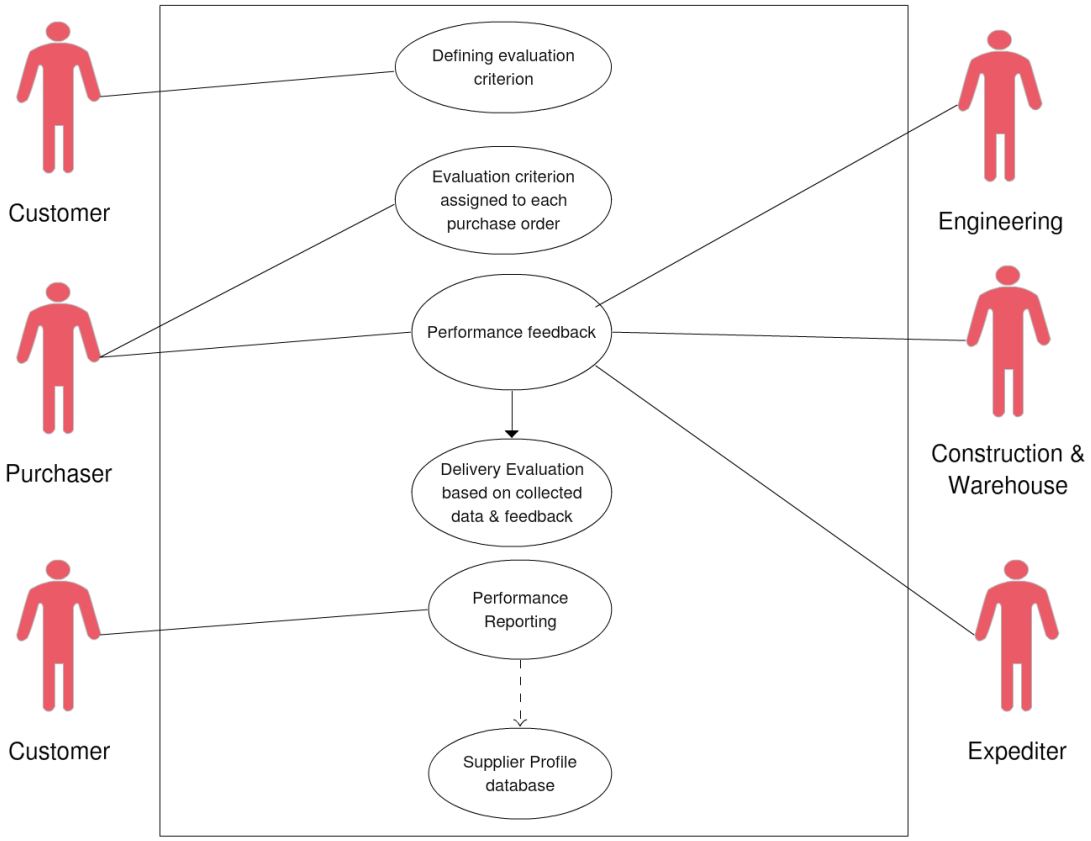

Figure 31 Use Case: Performance Management

The performance of a supplier can be derived from the performance of each of the purchases to that supplier. Additionally, supplier or procurement performance reporting for individual projects is also a point of interest for respective project stakeholders. Therefore, system should offer the functionality to generate the meaningful performance reports

specific to suppliers as well specific to projects. This performance evaluation should be stored in the supplier profiles and available as supplier history for future purchases and supplier requalification. Supplier qualification and information management is explained next.

8.4 Supplier Information Management

Supplier information management includes activities of building supplier database, supplier information collection, and maintenance of supplier profiles in the database. System should offer the functionality to create suppliers internally and new suppliers should be able to contact the company by registering themselves as potential suppliers through supplier portal. Basic information would be filled out and system should check the ensure that the defined requirements are met before proceeding. As explained in the previous chapter, the requirement and needed information varies according to the supplier's offering. Therefore, system should offer the functionality to categorize the suppliers and specify according to the category the detailed information requirements such as financial information, resource and capacity data, certifications. Figure 34 depicts the system-user interaction for these activities.

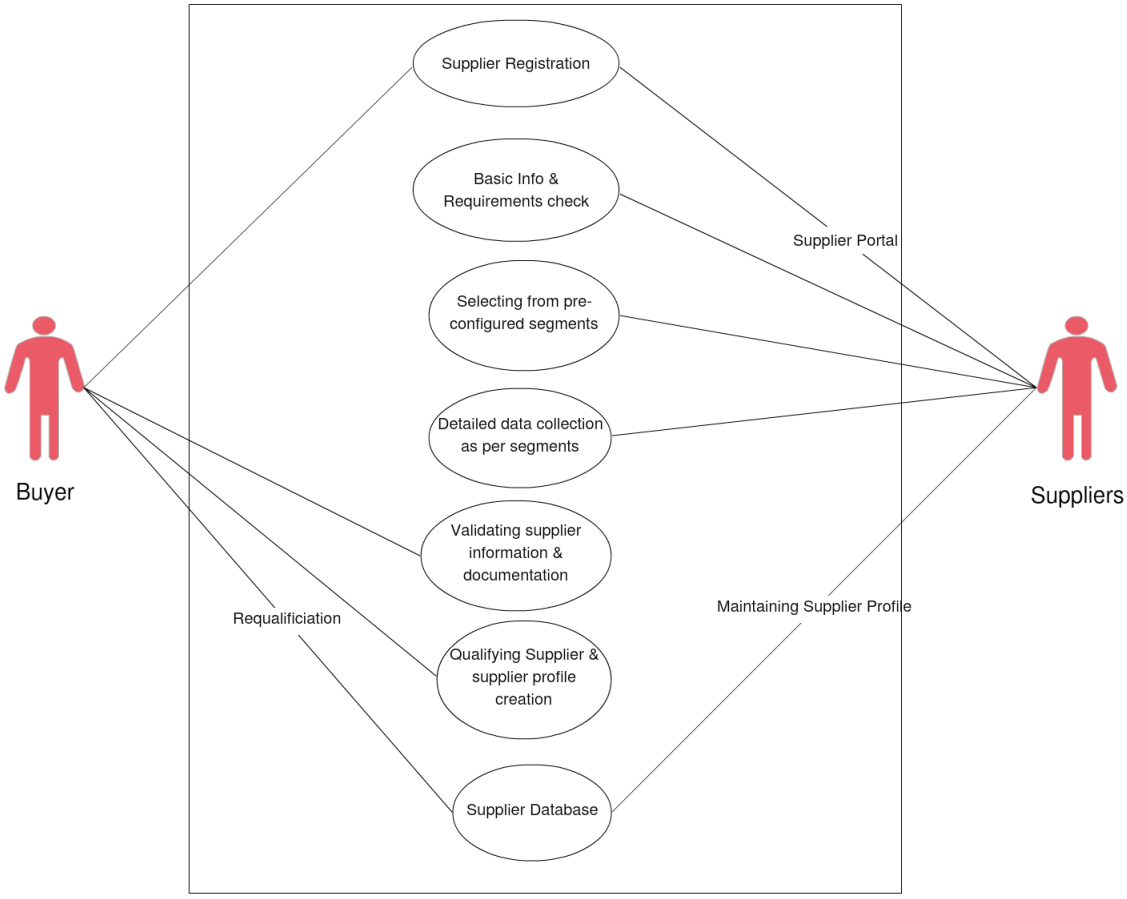

Figure 32 Use Case: Supplier Information Management

Information provided by the supplier into the system needs to be validated and in some cases manufacturing facilities have to be audited. System should offer the functionally to gather and manage this information in an intuitive manner. For example, most certifications are valid for defined period and need to be renewed regularly. System should point out and alert regarding these issues automatically. Once all the information is validated then suppliers are qualified for doing business with. System should offer the functionality to perform the qualification and creation of supplier profiles in the database after approval.

9. REQUIREMENTS SYNTHESIS

Chapter 9.1 presents the prioritization of the requirements, in Chapter 9.2 some of the commercially available software are evaluated against the requirements, other possible alternative solutions are discussed in finally some of the potential risks in the implementation process are discussed.

9.1 Prioritization of Requirements

Most of the commercially available supplier relationship management systems cover a wide range of activities and support for different functionalities varies. Additionally, acquiring and implementing a complete suite could be very expensive and the company might not even need all the functionalities. Based on the interviews data, the identified requirements are prioritized into three levels. Priority level one cover functionalities there are the most needed or provide significant value for the investment. In level two, those requirements are mentioned which are not the most pressing needs at moment but would be quite valuable. Lastly, the functionalities which might assist different activities are grouped in level three. The system does not necessarily have to support these functionalities; however, it would be nice to have these.

Table 9 Priority Level 1 Requirements

Requirement	**Description**
Supplier/ product segmentation	Ability to categorize suppliers or products to assign the most suitable of performance evaluation criteria
Defining evaluation criteria	Ability to configure multiple evaluation criteria (KPIs, scorecards), so that all the relevant information is collected.
Performance reporting	Comprehensive performance evaluation and reporting in as least resource intensive way as possible
Digital supplier database	Functionality to create and maintain a digital supplier database with all relevant information in supplier profiles.
Supplier qualification & Approval	Assessing the supplier qualification and creating approved supplier base.

Requisitioning	Creating, approving, and issuing purchase requisition in the system
Bids evaluation	Ability to perform technical and commercial evaluation of the bids submitted to the system
Order placement & signing-off	Hierarchical sign-offs for purchase orders, sending out orders to the suppliers, and receiving confirmations
Digital Product Catalogue	Ability to set-up centralized digital product catalogue
Search functionality	Ease of use and ability to search based on categories, product information etc.

Performance measurement and evaluation appear to be one of the most important aspects in respondents' views, and the need to systematically manage supplier performance is strongly stressed upon. Therefore, the system must offer the functionality to produce performance reports based on different evaluation criteria according to supplier/product segments. The functionality to develop a supplier database and perform supplier qualification are also given priority one. Implementing Digital tools for requisitioning and purchasing the process would reduce the need to use word processor and spreadsheet templates; this is also in line with the company's strategy to digitalize the processes. Since the current system to manage product information is poor, therefore, a digital catalogue with search functionality would be of great value.

Table 10 Priority Level 2 Requirements

Requirement	**Description**
Supplier registration	Registration of suppliers in the database internally or supplier themselves.
Supplier categorization	Ability to categorize suppliers based on the predefined criteria
Supplier information collection	Collecting the required supplier information according to respective categories
Validate supplier information	Validating the supplier information submitted into the system before qualifying.

External hyperlinks	Ability to add external hyperlinks for products to manufacturer's websites
Development plans and follow-up	Ability to create and share development plans and follow up on the needed actions
Electronic RFx documents	Ability to create and send out electronic RFx (request for information/quotation/bids) in the system
Collecting responses	Ability to collect the quotations/bids from this supplier in the system
Receiving and invoicing	Ability to receive the invoice, check against the received goods, and approve invoices for the payment
Supplier data maintenance	Collecting, storing, and maintaining supplier credentials documents. Flagging Active obsolete duplicate suppliers in the system
Supplier portal	A self-service supplier portal to manage supplier data, submit response to electronic RFx etc.

Priority level 2 is given to those requirements which would be needed to transfer the whole processes of supplier information management, performance management, and operative purchasing into a system there is also accessible suppliers. This would require the suppliers to use the system through suppliers' portal for various activities such as; RFx documents, bids submission, maintaining information in the supplier profiles, and maintaining catalogue information regarding their product offerings.

Table 11 Priority Level 3 Requirements

Requirement	**Description**
Notifications	Alerting concerned user when an action is required
Activity logging	Ability to log activities related to a delivery or a supplier
Product documentation	Ability to store product related documentation

Priority level three is assigned to the requirements that can be assistive to the system users for various activities. For example, alerting users through notifications missing information and pending tasks among others could be handy feature. Ability to log activities

for a particular project, suppliers or delivery could help make tracking and controlling efficient.

9.2 Recommendations for Implementation

9.2.1 Evaluation Commercially Available Solutions

Some of the renewed commercially available SRM solutions are evaluated against the requirements of that were defined in Chapter 7. The defined requirements were grouped into five categories. The evaluation of four solutions by different providers against these requirements is shown in Table 12

Table 12 Evaluation commercially available software against requirements.

	Fulfilled Requirements by Solution			
Category (No. of Requirements)	Ariba	BravoSolution	SupplyOn	SAP
Supplier Registration and Qualifications (5)	5	5	5	5
Product Catalogue (4)	4	4	0	4
Supplier Performance Management(4)	4	3	4	4
Operational Procurement (6)	5	5	6	6
Miscellaneous Requirements (4)	4	4	4	4

- **Ariba**
  Ariba provides on of the most comprehensive SRM that was evaluated against the requirements. The only requirement that Ariba does not seem to provide out of the box is the creation of purchase requisition based on the data collected from the design systems that are used in the case company. It also offers to ability to integrate payable management systems with it. Ariba was acquired by SAP in 2012 although both companies are still providing separate solutions, but Ariba system would be beneficial since case company already uses SAP ERP system.
- **BravoSolution Supply Management Suite**
  This solution meets all the requirements that Ariba suites meet; however, supplier performance evaluation functionalities are found to be limited. The benefits of this solution include availability in SaaS (software as a service) form and end-to-end sourcing capabilities.
- **SupplyOn**
  SupplyOn is a supply chain collaboration platform that also serves plant construction companies, similar to the case company, and therefore provides all the needed functionalities. The only draw back of this solution is that product catalog management system is not as good as supported by Ariba and BravoSolution.

- **SAP**
  The SAP suite seem to be the only one that meets all the requirements of the company. It has dedicated focus on process industry and service industry. Integrating it with the existing SAP ERP system would be easier as well.

9.2.2 Other Alternatives

Through the study of publicly available information about different SRM systems, many commercially available solutions seem to meet the elicited requirements. However, different SRM solutions developers support different functionalities to a different extent. Many solutions by the larger solution providers seem to meet the elicited requirements with some degree of customization. The solutions that are customized to the requirements, are generally quite expensive to implement and more difficult to maintain. Therefore, in order to avoid extensive customization, a detailed comparative analysis is required to decide which solution meets the most requirements out-of-the box.

One possible option to be used for supplier relationship management system is to implement a system based on the same platform that the company is using for customer relationship management. The elicited requirements would need to be compared against the offered functionalities of that platform. Since the company already has the experience of using the platform, therefore, it could be easier to implement the system. Additionally, there are many references of companies using the same platform four different kind of relationship management such as; venders, contacts, and other interest groups. The cost efficiency potential also seems quite good, as Business Systems Development Manager pointed out "*we already have that platform and the expansion in that system is done by €/user/month basis… sort it offers good scalability potential as well".*

At the time this study, a materials management system is under implementation of the case company, the implementation of material management system is part a multiphase project where new systems would be implemented for the various functions. The implementation of the system is in the design and process mapping phase. The Incoming system offers the functionalities that can be used – with some configuring- to meet some of the SRM requirements. How much configuring would be required to meet the company needs is not yet known since the implementation is still in early phases. However, this system also offers modules, which are not included in the part of the system that is currently under implementation, which can be used to meet the elicited requirements for SRM system. This offers good potential for scaling up to meet these requirements. Some of the potential risks during implication are discussed next.

9.2.3 Potential Risks during Implementation

When implementing the new system there are certain factors that the implementation team should be cautious about. Since the SRM system would affect many of the functions

in the case company, and considering the larger size of organization that is spread over many countries, a gradual implementation approach is more feasible. O'Leary (2000) has advocated adopting a phased approach to system deployment when size of the organization is large instead of all-at-once deployment. In the phased deployment approach, ERP systems are rolled out gradually, this makes the change management easier thus increasing the chances of successful implementation.

Implementation of new information systems can significantly affect the way people do their work and often it requires some modifications in business processes of the organization. In order to avoid many changes in the business processes organization sometimes tend to get the new system more customized to their processes. This approach can result in increased costs to the organizations, customizing the system requires extra work on implementation and maintenance of the system as well.(Remus, 2007) Therefore, it highly recommended that during the implementation, customization of the system should be avoided as much as possible and company should aim to adopt the system in the standard form as much as possible.

Finney (2007) has stated that involvement of the end user in the implementation processes is critical, along with sufficient training and education about the new systems. The sooner end-users understand the idea of the new system the better they will be positioned to adopt it in their work. Therefore, during implementation of SRM system representatives from each function and discipline should be involved from the initial stages. This would also positively affect the willingness to adapt to the change as well since personnel would be a part of bringing the change.

10. DISCUSSION AND CONCLUSION

This chapter presents a summary of the results in 10.1, Chapter 10.2 discusses the validity and reliability of the results. In the final section, contribution of this research and future research propositions are presented.

10.1 Summary of Results

Objective of the thesis was to define the requirement for a supplier relationship management system for an engineering, procurement, and construction firm. In order to define these requirements, as describe in Chapter 1, following questions were investigated:

- What are the current SRM practices?
- What activities of the SRM process are the most relevant to an EPC contractor?
- What are the processes related to supplier interaction where a digital system could bring improvement?

The first question was aimed at understanding the current state of supplier relationship management practices in the case company. The second question was intended to identify the benefits that an EPC contractor can have by implementing the supplier relationship management process. Lastly, the aim of the third question was to identify the key activities involved in the SRM process from the perspective of an EPC contractor.

For the first question, the processes of the case company were studied along with the project documentations of currently ongoing and the completed projects in the recent past. The case company currently delivers engineering, procurement, and construction management projects, and the role of the contractor in those projects is limited when it comes to supplier management. Contractors mostly use suppliers who are approved by the clients, therefore, the processes for supplier relationship management are not distinctly defined due the nature of these projects. However, the results presented in this thesis point towards the aspects that are considered important in the case company. When company moves towards undertaking more EPC projects and developing its own supplier base, then this information would be very useful.

The activities of the supplier relationship management process that are considered important in the academic literature were presented in Chapter 4; however, most of the discussion is focused on the manufacturing industry. To answer the second, results presented in Chapter 7 highlighted supplier performance management as the most crucial one. Many of the challenges highlighted by the respondents are related to supplier performance management. This could be because during any process industry investment project an EPC contractor has to work with a large number of suppliers. The nature of products varies

significantly; in case of goods suppliers, it can be from low value bulk materials to long lead-time high-tech process equipment. Moreover, for services providers, suppliers could be providing from skilled labor to expert design services. This great variation in suppliers requires a comprehensive strategy for measuring and controlling supplier performance. Supplier selection and evaluation are also crucial activities. As the number of suppliers involved in a big EPC project can be very large, and the potential new suppliers are always contacting the company as well. Therefore, a holistic approach to evaluate and qualifying suppliers is very important.

For the third question, operative purchasing was identified as one the areas where digital solution could bring improvements. Currently, much of this process, from requisition to invoice payment, involves a great deal of filling spreadsheet or word templets and transmission of those over email. Supporting the activities of operative purchasing with digital tools could significantly make the process more efficient, it could also improve the visibility throughout the process for measuring and controlling purposes. Implementing a digital catalog for the suppliers' products would also help the engineer while searching and selecting products for projects.

10.2 Validity and Reliability

Validity and reliability are the two cortical attributes of any scientific research. First, validity refers to the acceptability of research results. Joppe (2000) in (Golafshani, 2003) has described the validity of qualitative research as how truly a research measures which was intended to be measured or how truthful the research results are? Validity is further divided into internal and external validity (Ihantola and Kihn, 2011). Internal validity means how accurate the results are in the context of the study. External validity refers to the generalizability of the results, in other words external validity is the measure of how research results obtained in one setting can be use in another setting.

Internal validity of the findings is supported by the fact that the interviews conducted for the data collection were divided into three phases, after each phase of interviews, preliminary requirements were drawn. These preliminary requirements were validated in the subsequent interviews, so the results were validated by the users themselves. Additionally, the visual presentation of use cases also helped eliminate any ambiguities that arose due to the researchers' misinterpretation of results. External validity of these results is negatively affected by the fact that only one organization was understudy, the expressed needs for the participants could be circumstantial. Changing the organization might significantly influence the results. Therefor, the general applicability of these findings is rather limited.

Reliability of the measure of consistency in the results and the degree of bias, meaning would the same results be achieved if the same research procedure is followed by another researcher? Joppe (2000) in (Golafshani, 2003) has defined reliability as "The extent to

which results are consistent over time and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered reliable". Scientific reliability of the study is influenced by the fact that this research was done by a single researcher, therefore an individual's interpretation can be vulnerable to bias. However, similar with internal validity, reliability of the study is supported by that data collection approach, where requirements were validated by the participants of the study. The use of multiple sources of information also adds to the reliability of the study.

10.3 Contribution and Future Research

Most of the academic literature on supplier relationship management is focused on the manufacturing industry and there is lack of information from the perspective of a services firms, particularly for engineering project and construction firms. This thesis has aimed to identify the SRM activities that are most important from the perspective of an EPC firm. This report has also presented some of the areas related to supplier-buyer interaction where adopting digital solutions could bring the improvements. Since, many of the EPC or EPCM firm operate in a similar manner with some uniqueness to their practices; therefore, these results can be applicable to these firms as well.

Various ways to classify the supplier relationships were discussed in Chapter 3.2, these results give information about a suitable way an EPC could classify their relationship with the suppliers. It is quite apparent from the empirical data collected that there are at least three distinct groups of equipment that are procured by the case company for the projects; bulk material, standard equipment, and high-tach proprietary equipment. This information can be used to suggest how the supplier relationships for an EPC firm could be classified.

Bulk materials include piping material, nuts & bolts, and electrical cables among others. These are the least complex products that are bought in high volume but the price per unit usually low. Even though these are quite essential, but the substituting the suppliers is relatively easy since the manufacturing processes for these products are simpler, therefore there are many suppliers available for these products. Substituting these products is also easier, this makes their potential impact on the project schedule and cost lower.

The standard equipment such as sensors, mechanical valves, and electrical motors, are usually off-the shelf items and do not require any customization. Substituting these suppliers and products is easier; however, due to the long lead-time in some cases, their impact on the cost and schedule can be high. The third category of equipment is the high-tech proprietary equipment; this can be further be divided into two groups. One subgroup includes the packaged deliveries such as; boilers, compressors, and columns, these the most critical items in the project. These are made to the design and the whole projects schedule and other engineering work is dependent on these. Substituting these is practically impossible; any change in the design or schedule of these can have huge impact the

overall project. The have the longest lead-time that can be in years, there are very few potential suppliers for this kind equipment. The other subgroup can be considered of the equipment that is also made to the design but the lead-time for these is shorter than the first subgroup items such as control valves and equipment monitoring systems. The potential suppliers are still few but their substitution and impact on the overall project cost and schedule is lower in comparison with that of the first subgroup items.

As described above, the potential impact on the overall project cost and schedule, complexity of the equipment, lead-time, potential suppliers, the cost of equipment, and volume of the products, appear to be the distinguishing factors between products acquired for the project. These factors provide the bases for categorization of supplier relationships using Kraljic's (1983) portfolio matrix. The potential impact of the product on the overall project cost and schedule, and complexity of the equipment can be considered to the dimension "Profit impact" in the Kraljic's (1983) portfolio matrix. The cost and volume of the products, potential suppliers, and the lead-time can be correlated to "Supply risk" in Kraljic's model. Therefore, based on this research, the Kraljic's portfolio matrix can a suitable way an EPC contractor could classify the supplier relationships, this categorization is shown in Figure 35

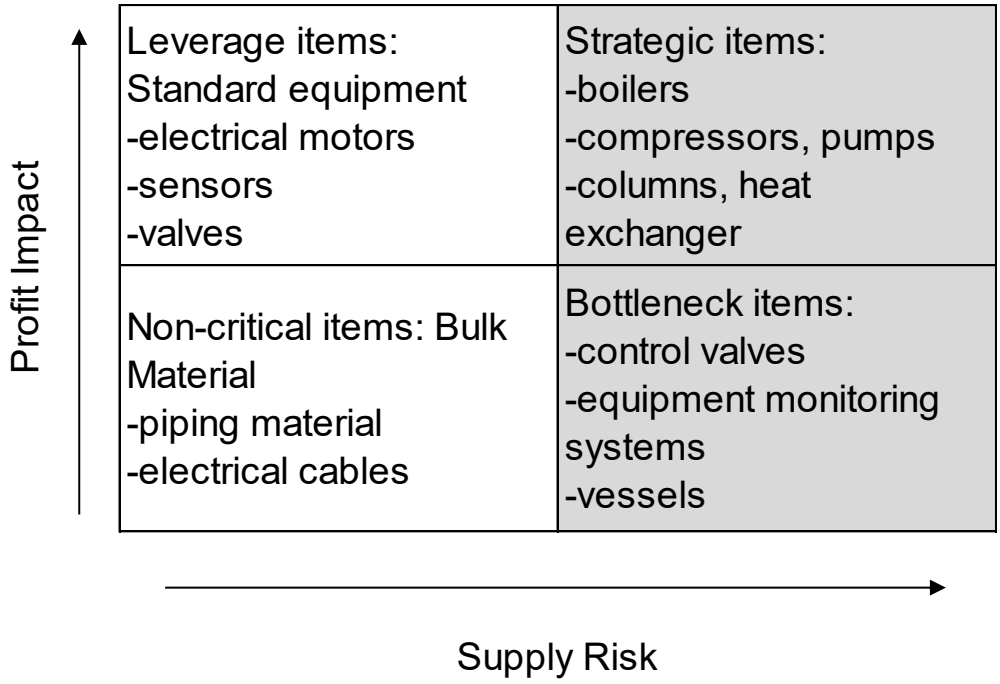

Figure 33 Classification of goods supplier relationships for EPC firm (adopted Kraljic, 1983)

For the purpose of this thesis, only employees on one company were interviewed. Inorder to access the general applicability of these results, a further study of other similar firms

could be conducted. The case company for the thesis delivers mostly EPCM projects therefore participants interviewed for this thesis did not have a great experience of EPC or Turnkey projects. These results to a large extent represent current needs, therefore, when the company moves towards carrying out EPC projects in future, a further investigation of those needs and requirements would be an interesting point of research.

The goods suppliers for an EPC project were analyzed in this research and different categories of equipment were identified. Based on these results, a suitable classification model was suggested. However, the suppliers of different services were not studied in detail; a deeper study of these services is needed to identify how the services can be further divided to suggest a relationship classification model for services providers. The need for a performance management strategy was highlighted in the results, some of the important performance parameters for each category of goods and services were identified. Investigating the performance parameters in detail for each category of product to devise a supplier performance management strategy would be quite useful for the company as well as a valuable addition to academic literature.

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Appendix A: Agenda for Interview session to gather requirements for Supplier Relationship Management System

Session Agenda:

The discussion session is focused on the below described areas. However, it is not meant be rigid and it is not supposed to restrict your thoughts or limit the discussion in anyway. It is only meant to serve as a map to drive the discussion forward in a systematic manner. So please feel free to express your ideas in the most suitable way for you.

Context Overview

Here you could share a high-level overview of your Business Area/functional responsibilities; it could include the key functions or processes that are performed in your department. This will help to get the specifics of the processes for the research and help me develop a better understanding of the business area.

Current State Business Processes

Here the focus is on the current state of the processes, particularly those processes that involve interaction with suppliers (work or services) for any intended purpose whatsoever. You could elaborate the processes, for example; the purpose and importance of the process start and end of the process result or output, how it is performed currently, and how does add value for you and the project.

Problems and Areas for Improvement

Here the goal is to explore the details for problems faced and potential areas for improvement. You could express your thoughts on the possible reasons behind the problems, how these problems can be addressed, and how a system can support the processes.

Future State

The goal here is to get the most important requirement for your function. You could share your thoughts on the rationale behind the requirements, why they are important, and what will they enable you to perform better.